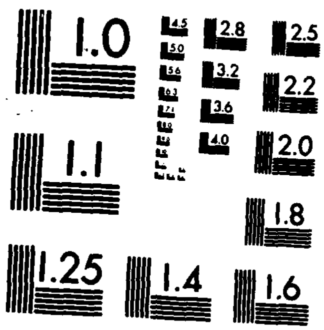
AD-A173 202 UHF (ULTRA HIGH FREQUENCY) MILITARY SATELLITE 1/1
COMMUNICATIONS GROUND EQUIPMENT INTEROPERABILITY(U)
M/A-COM GOVERNMENT SYSTEMS DIV VIENNA VA M FURMAN
UNCLASSIFIED 06 OCT 86 183 DCA/MSO-86-082A F/G 17/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

2

AD-A173 202

CENTER FOR COMMAND AND CONTROL, AND COMMUNICATIONS SYSTEMS (C^4S)

" EXCELLENCE IN C^3 SYSTEMS FOR NATIONAL DEFENSE"

UHF MILITARY SATELLITE COMMUNICATIONS GROUND EQUIPMENT INTEROPERABILITY

FINAL REPORT

October 1986

DEFENSE COMMUNICATIONS AGENCY

DEFENSE COMMUNICATIONS AGENCY

610042.0

86 1[illegible] 1[illegible] [illegible]04

CENTER FOR COMMAND AND CONTROL, AND COMMUNICATIONS SYSTEMS (C^4S)

" EXCELLENCE IN C^3 SYSTEMS FOR NATIONAL DEFENSE"

UHF MILITARY SATELLITE COMMUNICATIONS GROUND EQUIPMENT INTEROPERABILITY

FINAL REPORT

October 1986

DEFENSE COMMUNICATIONS AGENCY

610042.0

Table of Contents

List of Figures

List of Tables

ABSTRACT

This report addresses interoperability among users of Ultra High Frequency Military Satellite Communications (UHF MILSATCOM). The need for interoperability has gained importance in three areas. First is better identification of interoperability requirements for services which traditionally work together (for example Ground Mobile Forces (GMF) or Navy/Marine Corps during amphibious operations). Second is the increasing need for Commanders in Chief (CINCs) to communicate directly with their forces, including all the services. The third area is the increasing awareness that effective short-term crisis management requires interoperability between various services. These short-term crises often arise from unforeseen circumstances in which interoperability has not been identified as a requirement.

This report presents UHF interoperability from two major viewpoints: technical and managerial. Many papers addressing facets of interoperability for UHF MILSATCOM have been written (see References). Chapter 2 summarizes key references and comments on a variety of them. Key directives and memoranda are outlined that define service roles and criteria for interoperability standards. The communications equipment used with UHF MILSATCOM is presented in tabular form to address parameters of interest from an interoperability viewpoint. Candidates for interoperability standards are chosen for the near-term, mid-term, and far-term time frames. The final chapter summarizes problem areas and provides suggestions for improving interoperability.

1 INTRODUCTION

1.1 Objective

The development of standards for ground equipment would increase interoperability and efficient use of UHF resources without undue mutual interference. The problem of interference between users has been addressed previously using a simulation of various modulations, filters, and channel spacings (see Reference 19). This document addresses interoperability and how it could be improved by the development of ground equipment standards. In general, interoperability permits diverse users to communicate. The varying levels of interoperability are discussed in Section 1.3.

The increasing importance of interoperability is especially apparent in three areas. First, interoperability is required to facilitate normal planned joint operations between the services (and/or allies). For example, joint GMF exercises require interoperability between the Army and Air Force; traditional Navy and Marine Corps interoperability is crucial during amphibious operations. Allthough these cross-service operations can be planned ahead of time, attention to standards can ease both planning and implementing difficulties.

The second area of significance for interoperability is the increased need for the CINCs to communicate directly with their forces. This communication requires interoperability among the various services. Evidence of an increased effort to improve communications through interoperability is the Required Operational Capability (ROC5-84) from U.S. Commander in Chief, Atlantic (USCINCLANT), for interoperable UHF MILSATCOM capability.

The third important area for interoperability involves short-term crisis under unusual circumstances that require coordinated multiple-service operations. These situations differ from those discussed in the first area, in which requirements were identified and the operations were planned and implemented. Many short-term crisis are unforeseen and are never identified formally as requirements. Recent examples include Grenada, Lebanon peacekeeping operations, Falkland Islands, Iranian hostage rescue attempt, and responses to global terrorist activities. Reliable and timely communication in these cases depends on existing equipment (including hardware, software, and configuration) and procedures (including development, implementation, and training).

1.2 Scope

The scope includes surveying equipment used in UHF MILSATCOM, identifying areas requiring additional guidelines to permit interoperability, examining a range of options, and recommending a strategy for achieving a level of interoperability. The major tactical SATCOM systems under consideration are the Navy Fleet Satellite Communications System (FLTSATCOM), Air Force Satellite Communications (AFSATCOM), and UHF manpacks. Command and control of these systems are subordinate to the Unified and Specified CINCs. Since the breadth of tactical systems is massive, definitions for the items of commonality must be used to analyze the technical and managerial problems. The Department of Defense (DoD) management structure involved with interoperability issues is introduced. Elements of the managerial structure include DoD directives, executive agents, and their interoperability function. Technical elements defined by a generic tactical radio system are introduced. They include source and waveform processing, radio characteristics, and control protocol. The remainder of this chapter defines interoperability in terms of managerial and technical levels. It presents the methodology and evaluation criteria used for analysis and defines measures of effectiveness.

Chapter 2 is a description of the existing policies, directives, standards, and agreements for future standards.

Chapter 3 is a description of a survey of the existing UHF Systems. It also describes UHF system architectures, satellite systems, terminals, networks, proposed multiple access techniques, and gateway terminals. A generic terminal definition is introduced to give a basis for the comparisons. Source and waveform processing, radio characteristics, and network protocols comprise the elements of the generic terminal.

Chapter 4 is a description of candidates for standards. These are elements of the generic terminal that exhibit a high level of interoperability. It also describes tradeoff issues and advantages and disadvantages of various near-term, mid-term, and far-term approaches.

Chapter 5 is a summary of near-term, mid-term, and far-term recommendations on UHF interoperability with concluding remarks.

A reference section and an appendix on spectral inversion are included. The appendix is included to describe special radio characteristics of a popular popular UHF radio; namely, the AN/WSC-3.

1.3 Levels of Interoperability

The lack of a commonly accepted definition of interoperability led the Defense Communications Agency (DCA) to define levels of interoperability[1]. This detailed definition of interoperability allows system interoperability objectives to be stated in very specific terms. The following paragraphs present an overview of the DCA's interoperability definition and its application in evaluating the feasibility of satisfying the UHF MILSATCOM interoperability requirements.

The two most important factors constraining interoperability are technical interfaces and management/control philosophies. The range of technical interface possibilities include:

1. It is impractical to interface user communities.

2. It is feasible to develop an interface box to allow interoperation.

3. One of the two systems can be redesigned (or modified) to allow connection between systems without having to utilize interface boxes.

4. There is no technical interface problem; both systems are compatible.

Management/controller possibilities include:

1. Complete independence between systems; i.e., requires two terminals for a user who is member of both communities

2. Memorandum of understanding to share resources

3. Agreement for users to interconnect to one another with no impact on individual systems

4. Agreement for users to interconnect to one another, but retain individual prerogatives

5. Willingness to accept significant impact from actions taken by user and management/control of external systems

[1]Circa 1982; prepared by Rockwell International for DCA

6. Separate systems placed under common management/control, thus becoming the same system

By combining these two measures, it is possible to derive a spectrum of interoperability. The seven levels of interoperability considered are:

1. Separate systems (1,1)
2. Shared resources (1,2)
3. Gateways (2,3)
4. Multiple entry points (2,4)
5. Conformable/compatible systems (3,4)
6. Completely interoperable system (3,5)
7. Same system (4,6).

The numbers following the levels of interoperability indicate the technical interface possibility and the management/control possibility respectively. The level of interoperability increases as the number of the option increases. Level 1 represents no interoperability between the systems involved. The benefit of shared resources (level 2) is the "economy of scale" that is gained when communications are traversing the same network and using the same transmission facilities. With gateways (level 3), it is possible to cross over from one system to another, thus permitting the user in one system to access the other system. This, albeit low, level of communication interoperability is achieved when a few gateways are employed. As the number of gateways increases, the level of interoperability moves up the scale to multiple entry points (level 4). Increasing the number of gateways is a means of enhancing survivability; however, it also increases terminal complexity.

Conformable/compatible systems (level 5) is a higher level of interoperability. While level 5 does not demand that the systems be identical, it does imply that provisions have been made for at least one of the systems to accept the characteristics of the other system. A still higher level of interoperability would be defined as completely interoperable systems (level 6). This level requires the design/fabrication of hardware and software to make it possible to cross from one system to another at any point in either

system. The highest level of interoperability would be the integration of separate systems into one system (level 7). In this case, all resources are under the same management/control.

An important point to recognize is that it is impossible to express the relative merits of each interoperability alternative by a single criterion. Criteria can be formed at any level of generality; however, they always can be subdivided into lower levels, creating a decision-tree structure. Such a structure is shown in Figure 1-1.

1.4 Methodology and Evaluation Criteria

This section describes the evaluation criteria and methodology that were used to compare the alternatives for standardization of the Ground Segment. The evaluation criteria are selected to ensure that they account for the significant characteristics of the alternatives. The following sections describe the methodology and the evaluation criteria, respectively. As shown in Figure 1-2, interoperability among terminals will be investigated on four layers:

- **Source Processing**: Includes voice and/or data equipment, encryptor and decryptor, and multiplexers (options).

- **Waveform Processing**: Includes the modem, interleaver and deinterleaver (optional), and coder and decoder.

- **RF/IF**: Includes the antenna, diplexer, high-power amplifier, low-noise amplifier, up-converter, and down-converter.

- **Network Processing**: Includes all the control functions that are applied to the individual equipment mentioned above as well as to the network connectivities.

The parameters of interest for interoperability are described in the following sections.

1.4.1 Source Processing

The parameters of interest in source processing are as follows:

- Data/Teletype/Record

    - o Character representation convention:
      American Standard Code for Information Interchange (ASCII): 8, 7, 6 bit

Figure 1-1. Measures of Effectiveness

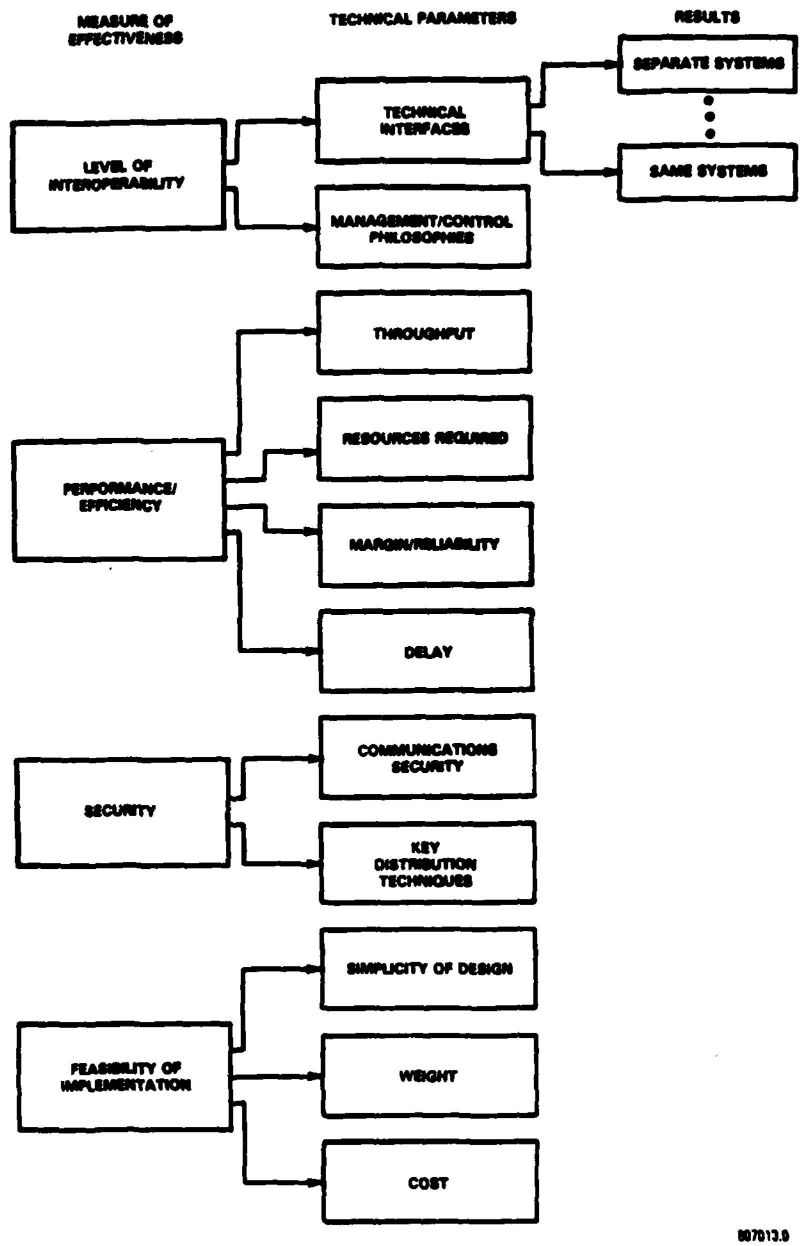
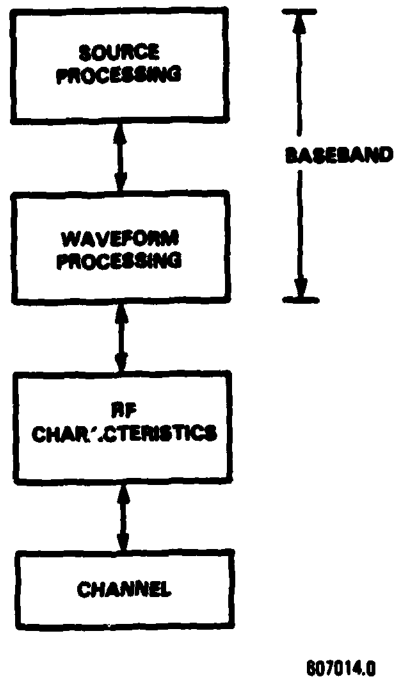


Figure 1-2. Interoperability Layers



  - o Baudot

- Voice

  - o Analog - AM/FM

  - o Digital Voice Encoding

    - Linear Prediction Code (LPC-10)

    - Continuously Variable Slope Delta Modulation (CVSD)

    - Pulse Code Modulation (PCM)

- Encryption

  - o Encryption method; Analog/Digital

  - o Key distribution

1.4.2 Waveform Processing

The parameters of interest in the waveform processing layer are as follows:

- Modulation

  - o Type

  - o Data rates

  - o Differential encoding methods and conventions

- Error correction coding

  - o Type

  - o Code Rates

- Interleaving

- Link Control

1.4.3 Radio Frequency/Intermediate Frequency (RF/IF)

The parameters of interest in the RF/IF layer are as follows:

- EIRP - Effective Isotropic Radiated Power of the terminal.
- G/T - The gain/temperature ratio representing the figure of merit for the receiver.
- Full duplex, half duplex or simplex - Whether the RF can transmit and receive simultaneously. If this can be accomplished, what are characteristics of the duplexer filters.
- Tunability - Whether the radio/modem can tune in 5-kHz or 25-kHz steps.
- Offsets - How the translation between the transmit and receive frequencies is handled. Offsets are obtained by predefined hardware, firmware, or software constraints specific to each satellite transponder.

1.4.4 Network Processing

The areas of interest in the network processing/control layer are as follows:

- UHF Satellite Network Protocol
- Gateway Protocol (Example: NAVCOMPARS)
- Exterior Gateway Protocol (Example: AFSAT I to CUDIXS)

1.4.5 Measures of Effectiveness

The effectiveness of each alternative will be measured according to the following basis:

- Level of interoperability
- Performance/efficiency
- Security
- Feasibility of implementation

These metrics and their functional relationship to the terminal parameters are shown in Figure 1-3.

1.4.5.1 Performance/Efficiency

In order to evaluate various candidates for interoperability among the various services, a measure of performance/efficiency is needed. Depending on exactly what alternatives are being considered, throughput may be a variety of units. Examples are bits per second or messages (of specified size) per hour. If a demand assignment system is being considered, throughput versus delay is another common measure of performance and may be represented by a curve of delay for a range of throughput. Efficiency is generally a ratio of performance to resources. Often this is expressed as the ratio of performance to the maximum ideal performance ideal case. An example of efficiency is throughput as a percentage of the ideal case. Efficiency can also be used in terms of throughput per satellite channel, throughput per watt of satellite power, or per hertz (i.e., bits/sec).

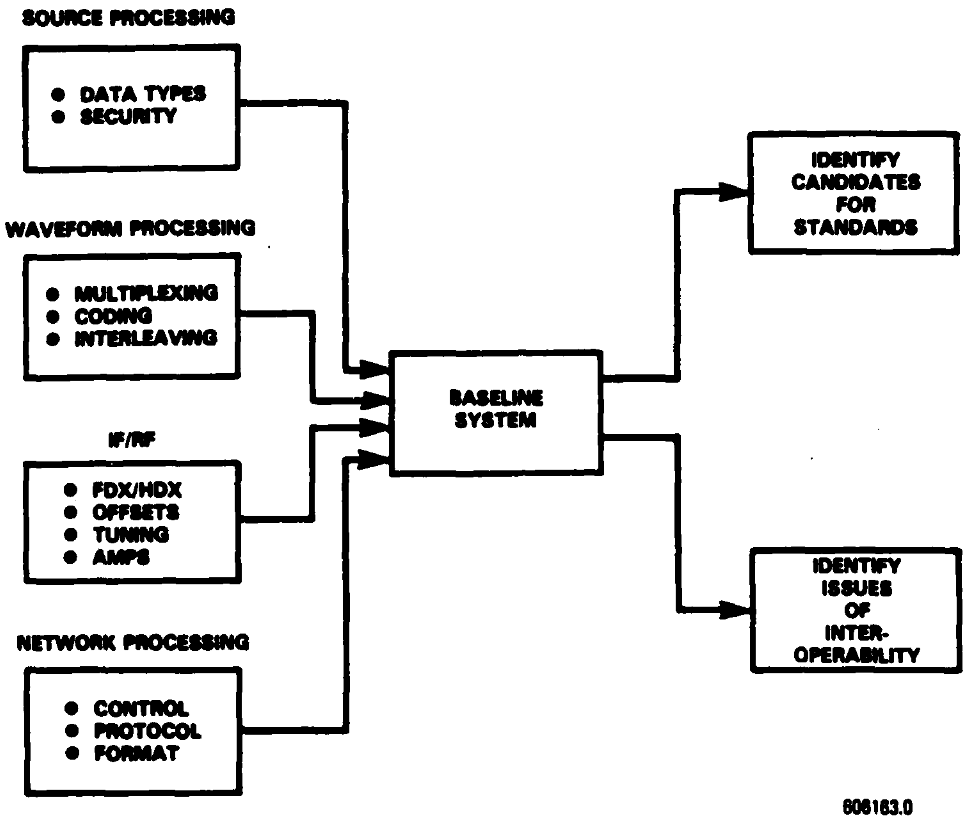
1.4.5.2 Security

Encryption may exacerbate interoperability difficulties since compatibility with one more set of equipment is required. Nonetheless, security must be included as a measure of effectiveness. If an alternative does not permit encryption, this fact must be weighed against its possible advantages. Ease of key distribution is another security item to be considered. Electronic key distribution may permit quickly setting up a call or circuit among groups or parties that usually do not require communications. Hard copy control key distribution, on the other hand, may require considerable lead time to set up.

1.4.5.3 Feasibility of Implementation

A fourth measure of effectiveness is the feasibility of implementation. This measure includes simplicity of design, weight, and cost. This criterion is important because an alternative that might otherwise appear attractive may not be feasible due to cost or design complexity.

Figure 1-3. Subtask Aa Flow Diagram



2 UHF Policy and Managerial Background

2.1 UHF Background

The Lincoln Experimental Satellites (LES 1 through 9, a 1965 product of the MIT Lincoln Laboratories) and the TACSAT I (developed in 1969 under the Tactical Satellite Communications [TACSATCOM] Program) were the genesis of the current UHF FLTSATCOM and AFSATCOM Systems. These systems were developed to test satellite attitude control, satellite crosslinks, and earth terminal links. By 1971, however, the Air Force and Navy each proposed separate Development Concept Papers (DCPs 100 and 99, respectively) which were tailored to meet their respective mobile user needs. The Navy proposed a configuration of three geostationary satellites, while the Air Force proposed a five-satellite constellation; two inclined orbit and three geostationary orbit. These proposals resulted from a failure to develop and gain approval for a cost-effective tri-service (USAF, USN, and USMC) TACSATCOM system. The DoD approved the Navy's FLTSATCOM plans based on shared use with the Air Force. The Air Force redirected its AFSATCOM efforts toward FLTSATCOM, and the Navy added a fourth satellite to enhance system capacity, coverage and flexibility. In 1976, the Air Force obtained polar coverage with Satellite Data Systems (SDS). As these satellite systems emerged, the Air Force and Navy shared some of the space segment, but the characteristics of ground/airborne terminal equipment diverged. In the current geostationary orbit space segment configuration, there are two UHF satellite constellations (LEASAT and FLTSAT) and plans exist for a follow-on UHF constellation. The principal user of AFSATCOM is the Strategic Air Command (SAC) configured as command post hubs with force element spokes at 75 bps data. The Navy's FLTSATCOM system is a conglomerate of information exchange networks, secure record/voice/data systems, gateway terminals, and broadcast channels. The Army also uses UHF SATCOM for manpack and transportable terminals.

There are many difficult issues that must be resolved before full UHF interoperability between the DoD organizations can be provided. Since each organization independently designed its own communications networks, equipment application and diversity are widespread. This chapter provides an overview of DoD organizations and documents that mandate or reference interoperability requirements. Overviews of the design plans for the UHF follow-on 5 and 25 kHz channels are also presented.

2.2 UHF Interoperability Management Functions

The Joint Tactical Command, Control, and Communications Agency (**JTC^3A**) is the DoD executive agent responsible for reviewing interoperability requirements and generating performance specifications to ensure equipment interoperability. The JTC^3A was formed to consolidate the four following groups: the Joint Tactical Communications (**Tri-Tac**) Program, the Joint Interoperability of Tactical Command and Control System (**JINTACCS**), the Joint Test Element (**JTE**), and the Joint Interoperability Test Facility (**JITF**). The JTC^3A addresses technical issues on transmission and communication security, switching, control and access, automation and software, system and network analysis, tactical data systems, and procedures. Specific organization goals are to establish methodologies for interoperability from a viewpoint of management. JTC^3A tasks include:

- Establish review boards to examine the need for one-of-a-kind equipment use
- Determine operational needs for compatibility and interoperability among C^3I systems
- Provide information on tactical C^3I development, acquisition, and modification of equipment for Assistant Secretary of Defense C^3I ($ASDC^3I$) review and decision
- Develop specific test and evaluation interface standards and operational procedures

In addition to the JTC^3A role as the executive agent, tactical UHF planning tasks have been distributed among the services. The Navy and Air Force are providing interoperable 25-kHz and 5-kHz UHF TDMA/DAMA channel standards, respectively. In addition, the Navy and Air Force are responsible for research and development test and evaluation of the Multiple Access Satellite (MACS) modem and the UHF Satellite Terminal Systems (USTS) modem. The Army is tasked with far-term management planning and development and procurement of UHF manpack terminals, including the miniature UHF manpack terminal (MINTERM) development.

Figure 2-1 is a broad summary of DoD groups that are concerned with UHF interoperability. Management functions describe activities for policy making, executive agents, research and development, test and evaluation, acquisitions, and operations/commands.

Figure 2-1. Interoperability Management Functions Within the DoD

DoD Group	Management Function
	Policy and Requirements
OSD	C^3I
JCS	OJCS-RD&E: C^3S
Army	EAIM: (DAIM-PSI)
Army	Requirements: (DAMO-FDR): Force development requirements
Navy	CNO [OPNAV (943C)]
Air Force	CSAF (RDS)
JTC^3A	Executive agent for all tactical interoperability issues
Army	USASATCOMA: Executive agent/administrator UHF Manpacks
Navy	SPAWAR [PDW-106 (Space), PDW 110 (Ground)]: UHF - 25 kHz standard & MACS Modem
Air Force	ESD/XRC: UHF - 5 kHz standard & USTS Modem
DCA	MSO: UHF Standards and Criteria
DCA	MSO - All MILSATCOM systems architecture
Army	Manpack/ANDVT interoperability testing
Navy	MACS modem development
Navy	Manpack/ANDVT interoperability testing, Naval Electronic Sys. Engrg. Activity (NESEA)
Air Force	ESD/OCM: (airlift, weather systems and weather traffic control), USTS modem architecture
Air Force	USTS Development, ROME Air Development Ctr. (RADC)
	Operations/Commands
CINCS	Unified and Specified Commands
Army	Army Informations Systems Command (formally ACC) Ft Huachuca
Navy	Navy Space Command
Navy	Naval Telecommunications Command
Air Force	Air Force Communications Command (AFCC):
Air Force	SCF: Maintenance of station keeping, testing and satellite frequency plans FLTSAT.

2.3 DoD Directives

The DoD has written or sponsored numerous documents establishing interoperability policies for tactical UHF SATCOM. One such document is DoD Directive 4630.5. Indeed, the *role and strength of the* JTC^{3}A (*discussed in the previous section) are results of* Directive 4630.5. This section provides an overview of policy statements contained in this and subsequent DoD documents and states the level of their implementation.

2.3.1 Directive 4630.5

In 1985 the DoD issued Directive 4630.5 - "Compatibility and Interoperability of Tactical Command, Control, Communications and Intelligence Systems" (C^{3}I) in an effort to update policies that were formed prior to satellite systems. The directive's intent is to ensure that the DoD will seek tactical C^{3}I systems and equipment that is identical or directly interoperable between the services.

2.3.2 MJCS-237-82

This memorandum was developed and approved by JCS for the Under Secretary of Defense Research and Engineering (USDR&E) concerning nonprocessed UHF SATCOM Terminal Architecture. Four sections address responsibility, background, scope and coordination of UHF man-transportable radios. A background section reviews the unanticipated procurement of inexpensive, low-powered, and portable UHF SATCOM terminals. *The scope section defines which terminal types apply to this memorandum* and excludes those designed and programmed to satisfy validated requirements. The coordination section summarizes the intent of the memorandum, namely, that the OJCS along with the services and the MSO should continue to work to solve the interoperability problem. An enclosure places management and technical requirement specifications on nonprocessed UHF SATCOM terminals. A summary of the enclosure follows:

- Management Requirements

  - o The Army is the single manager for acquisition and life cycle of all manpacks. It is also responsible for program funding including all required research and development of manpack terminals. The Army will develop logistics support and maintenance, and is required to ledger and track all new terminal procurement.

  - o Other services and agencies are to ensure that procedures are

established for administrative control of terminals. They must provide the Army with funding to procure any such terminals.

- Technical Requirements

  - o Terminals must have 5-kHz tunability in the 235 to 399.9-MHz range.
  - o Local oscillator frequency drift should be $\leq 1{:}10^6$.
  - o Terminals with noncontrollable power output shall be between 18 and 21 dBW (more power is allowable for controllable power output terminals).
  - o The terminal $(G/T)/(E_b/N_o)$ shall be greater than or equal to -31.9 dBW/^{0}K @ 10^{-3} bit error rate (BER) and -34.7 dBW/^{0}K @10^{-5} BER.
  - o Effects of adjacent channel interference (ACI) shall average less than 5 dBW at a 5-kHz offset over a 5-kHz bandwidth and -3 dBW at a 10-kHz offset and 5-kHz bandwidth operating at data rate of 2.6 kbps or less.
  - o 2.4 kbps data rate is required.
  - o Coding rate 1/2 and 3/4 convolutional (if used).

The services comply with the technical requirements of MJCS-237-82. The Army's management requirements implemented as a result of this memo for UHF manpacks have been described in the GMF SATCOM Program Plan (November 1985). Ongoing actions are further detailing this requirement.

2.3.3 MJCS-164-84

MJCS-164-84 was generated and approved by JCS as supplemental policies and standards to the previous memorandum. MJCS-164-84 requires conformance with the following items:

- Narrowband voice at 2.4 kbps with LPC-10 digitizer: Compatible Advanced Narrowband Digital Voice Terminal (ANDVT)
- KYV-5 COMSEC or interoperable equivalent
- Shaped Binary Phase Shift Keying (SBPSK) or compatible modulation
- Uncoded digital voice
- 5-kHz tunability for all non-DAMAtized radios which will use secure voice.

- Services to provide a transition strategy with fiscal planning
- Delay requirement to modify existing equipments until production quantities of KYV-5s become available

Additional objectives and requirements are stated in MJCS-164-84. The objective is that all nonprocessed UHF SATCOM terminals operate as efficiently as possible. Another requirement is that the services determine which UHF terminals are subject to the above requirements and provide a fiscally supported transition strategy to implement the requirements of this memorandum.

2.3.4 DCA/MSO Memorandum

The DCA/MSO has reviewed various policy and plans of the services and has prepared a memorandum (Reference 2) stating its viewpoint on the UHF MILSATCOM follow-on system. All parts of the communication system are addressed; however, this section will overview only the interoperability issues. DCA/MSO states (Reference 2) that the largest overuse of system resources is the 16-kbps VINSON secure voice terminal. This system requires full dedication of one 25-kHz channel. Even with an early mid-term time-table set for ANDVT secure voice (2.4 kbps), satellite capacity still will be burdened with the continued and growing use of the 16-kbps equipment. DCA/MSO also believes that both Navy and Air Force (MACS/USTS) modem designs are good, and no critical commentary is necessary except to clearly state what is the level of interoperability.

The DCA (Reference 25) has recently submitted the "UHF SATCOM Terminal Technical Criteria" memorandum to the ASDC^{3}I, Director for C^3 Systems, Organization of the JCS, for their review and approval. Eight sections describe general background, definitions, scope, technical criteria (two parts), compliance tests, effective dates, and exception waivers. This document is intended to supersede technical criteria contained in MJCS-237-82 and MJCS-164-84. The definitions and scope sections define a "nonprocessed channel" and what UHF terminals are under this criteria respectively. Nonprocessed channels are defined as a satellite channel capable of amplifying and retransmitting a received signal. (This excludes 500 kHz CDMA mode and the nonprocessed 5-kHz AFSAT control channel.) A UHF terminal definition includes the following equipment:

- Modem - supplies the modulation signal and receives a demodulated signal

- Radio set - carrier modulator through the final RF output amplifies and receiver front end through the carrier demodulator

- RF transmission line and antenna

The scope section defines two UHF terminals categories. The first terminal category is capable of operating in a nonprocessed channel (excluding validated AFSATCOM/FLTSATCOM requirements defined in their respective concepts of operations) and the second category includes all other secure voice terminals operating in nonDAMAtized UHF networks but not specified by the first category. The first terminal set of technical criteria specifies:

- EIRP; Fixed: 18 dBW minimum to 21 dBW maximum; Adjustable: higher levels allowable with adjustable power level

- $(G/T)/(E_b/N_0)$ ratio; ≥ -31.9 dB at a BER of 10^{-3} and ≥ -34.7 dB at a BER of 10^{-5}

- Adjacent channel emission; for all carrier modulations with bit rates less than 10 kbps, 14 tabular values of frequency removed from carrier with maximum allowable EIRP in a 5 kHz band.

- Tunability; 5-kHz increments (235 to 399.9 MHz.)

- Frequency Tolerance; $1{:}10^6$- long term plus short term

- Data Rates; 2.4 kbps required, others acceptable

- Modulation:

  - o SBPSK at 2.4 kbps, no error detection or correction coding required

  - o Constant amplitude envelope

  - o A 50% transition period with a linear phase rate of change

  - o The direction of phase vector rotation will always be opposite that of the previous rotation

  - o All other modulations methods determined by other user requirements shall have a constant amplitude envelope

- Carrier Acquisition;

  - o Random bit pattern
  - o Received C/KT $\leq$ 44 dB
  - o Frequency offset ± 700 Hz.
  - o Acquisition time $\leq$ 250 msec.
  - o Probablility of lock $\geq$ 99.9%

- A compatible secure voice modem interface (ANDVT with KYV-5 COMSEC)

- Voice digitizer; a narrowband 2400-bps data rate digitizer employing the DoD standard ANDVT/LPC-10 algorithm

- COMSEC - A KYV-5 COMSEC device or one that will interoperate with it

The second set of technical criteria for secure voice terminals describes the following:

- Radio Set - Tunability, frequency tolerance, modulation, secure voice interface identical (or compatible) to the first technical criteria.

- Secure Voice Modem - Voice digitizer and COMSEC identical (or compatible) to the first technical criteria.

- Interoperability - Terminals of the first technical criteria will interface with terminals of the second criteria.

- A compliance tests section that certifies interoperability for radio sets, antennas, and NSA-approved secure voice modems meeting the technical criteria. Interoperability tests will be performed among and between all terminals meeting the criteria.

- Effective dates apply immediately to all new purchases of radios, antennas and secure voice modems certified by the Army as meeting the first technical criteria. Effective dates for existing terminals of the first catagory and terminals described by the second technical criteria shall be met when secure voice modems become available in production quantities (est. 1988).

- Exception waivers may be granted on a case-by-case basis.

2.4 DoD Standards

Standards have been established or are in the development process for UHF channel operations. The intent of these standards is to ensure an orderly and compatible growth in the military UHF SATCOM arena. The following sections highlight these standards.

2.4.1 5 kHz Standard

The Air Force has been directed to develop the 5-kHz UHF channel interoperability standard. Under ESD contract, the Mitre Corp. (Reference 9) provides an extensive analysis of Air Force UHF requirements and compares them to methods proposed or in use by the Navy for TDMA/DAMA. Several important factors are compared concerning modulation, adjacent channel interference, and link budget considerations. Detailed frame design is not included; however, TDMA/DAMA concepts are. The following items highlight the conclusions and recommendations:

- 5-kHz Interoperation
  5-kHz channel interoperation with the Navy's TDMA-2, TDMA-3, and proposed TDMA-4 is not recommended.

- OQPSK
  Offset QPSK modulation is recommended for bandwidth efficiency and to minimize losses due to adjacent channel interference, doppler shift, and timing jitter.

- TDMA/DAMA
  The Navy TDMA/DAMA is not practical for Air Force operations for the following reasons:

  - Burst rates do not encompass efficient Air Force use.
  - Frame formats are too complex.
  - The use of frame time is inefficient.

Additionally, comments and recommendations are included that address the Navy's proposed 25-kHz standard. This report describes agreement with the major transmission characteristics for interoperation, but questions the need for control and return orderwires. The report also describes an objection to additional cryptographic equipment necessary to process the orderwire signalling for the Navy's format. It claims that frame slot use could be scheduled in a static way, strictly for interoperation purposes. The

need to signal via orderwire (OW) and to decrypt the OW would then be unnecessary. An obvious advantage from the Air Force's point of view is the minimum impact on implementing new equipment.

2.4.2 25-kHz Waveform Standard

The 25-kHz TDMA/DAMA waveform standard for UHF SATCOM is based on the Navy's TD-1271 modem. Reference 4 is a detailed draft proposal of this standard, which was developed by the DCA/MSO. This document proposes a three-segment TDMA user frame choice which could result in nearly 2000 specific format combinations. These combinations are either in use or are proposed for FLTSAT, LEASAT, and the Follow-on UHF MILSATCOM spacecraft systems. The current information exchange systems are compatible with fixed slot assignment in the TDMA frame. Detailed attention is given to the waveform structure, modulation requirements, orderwire commands, and control. This document describes the following features:

- Frame Size
  A minor frame is 1.3866 seconds with 8 frames/master frame (11.093 seconds)

- Frame Slot Functions
  Five subframe functions are implemented; an orderwire slot, a return orderwire slot, a range slot, a link test (bit errors) slot, and user data slots.

- Modulation
  BPSK and DQPSK modulation is used at 9.6 ksps,[2] 19.2 ksps (BPSK) and 32. ksps (DQPSK).

- Forward Error Correction Coding (FEC)
  FEC rate 1/2 and rate 3/4 (constraint lengths 7 and 9, respectively) convolutional codes are used. The codewords for rate 1/2 and rate 3/4 are transparent.

- Interleaving
  Random interleaving with a block depth of 224 symbols is used.

This standard is JCS approved except for the specific interoperable frame formats.

[2] Baseband binary symbols per second.

2.4.3 ANDVT Standard

The Advanced Narrowband Digital Voice Terminal (ANDVT) is a modern equipment standard (Reference 7) that requires the components that implement baseband processing to be housed into a single package. Components include the voice digitizing algorithm, data rates, and encryption. Use of the ANDVT is a significant step toward interoperability because most intra-service equipment does not support full baseband compatibility.

2.4.4 Manpack Criteria

Manpack criteria are currently described in the JCS memorandums MJCS-237-82 and MJCS-164-84. The Army is currenty evaluating manpack radios for certification. These standards ensure modulation, encryption, and radio characteristic uniformity but do not specify channel control characteristics. Such specifications would be premature at this time. They are being revised into one technical criteria document to be approved by the OSDC^{3}I and JCSC^{3}S.

3 UHF Systems Survey

This chapter examines tactical SATCOM systems in four major areas: systems architecture, satellite systems and channel characteristics, terminals, and existing or planned network systems controlling or available to the UHF community. The prime UHF users are Navy FLTSATCOM, Air Force AFSATCOM, Army GMF manpacks, and Joint Service (CINCs).

3.1 Systems Architecture

Systems architecture is the broadest overview of the satellite, terminal, and controlling elements that make up a network system. This section is provided to indicate overall capabilities, quantities, and operational procedures inherent in each of the service tactical SATCOM programs. The intent of this section is to show that the Army, Navy, and Air Force have similar architectures in terms of requirements but vary considerably in terms of terminal and network configurations.

3.1.1 Navy - FLTSATCOM

Navy UHF satellite communications architecture supports 46 types of ships, 2 types of submarines, P-3C aircraft, and 36 shore stations. Equipment size and complexity vary with location; however, all RF links that handle voice and message traffic are under processor control. The system may operate its six networks as separate entities, but the normal integration of these networks provides DoD long-haul communications. A backup system provides communication capabilities in the event of an outage. Typical configurations include a fleet of ships or submarines under control of a Naval Communications Area Master Station (NAVCAMS). Each subsystem consists of two basic parts: the baseband equipment to collect and control data and a RF terminal. NAVCAMS are distributed globally to support worldwide capabilities. The Navy supports two transportable ground stations that can provide transfer orbit commands to FLTSAT on a back-up basis. The Navy Electronic Systems Command controls the logistics that support the maintenance, training, and system documentation of its systems.

3.1.2 Air Force - AFSATCOM

The Air Force UHF architecture is based on 75-bps FSK. Typical configurations are command-post/force-element networks that are on a hunt-and-peck (random access), user-controlled network, or TDM access. TDM access includes polling, pre-mission slot assigned, or a satellite control processed network. Force elements include the FB 111, the RC 135, the B-52, and the EC-135 aircraft. Most terminals fall into one of three categories as the Type 1, 3A, or 12 terminal; the latter two are capable of supporting command post functions. These terminals support a variety of half- and full-duplex links and may simultaneously access one to three satellites. All terminals have the selection capability to access one of 59 slots for the full range of tuning. These terminals also support a line-of-sight (LOS) FM-voice capability. In addition to the geostationary FLTSAT network, the Air Force employs the inclined orbit SDS satellite system. SDS application, however, is primarily for the Single Integrated Operational Plan (SIOP) processed channels.

3.1.3 Army - TACSAT

AN/PSC-3 UHF radio manpacks are commonly used to provide troops with mobile long-distance communications.

3.2 Satellite Systems and Channel Characteristics

Table 3-1 details some of the nonprocessed UHF channel characteristics for the three satellite types used by the DoD organizations. These satellites include networks for the USA, USN, USMC, and USAF. Power, channelization, bandwidth, and other RF channel characteristics are presented. The number of planned orbital locations and number of frequency plans for the Follow-on UHF satellite are under development. Figure 3-1. details the frequency plans for the various satellites. Certain networks plan to transition from the FLTSAT and LEASAT constellations to MILSTAR.

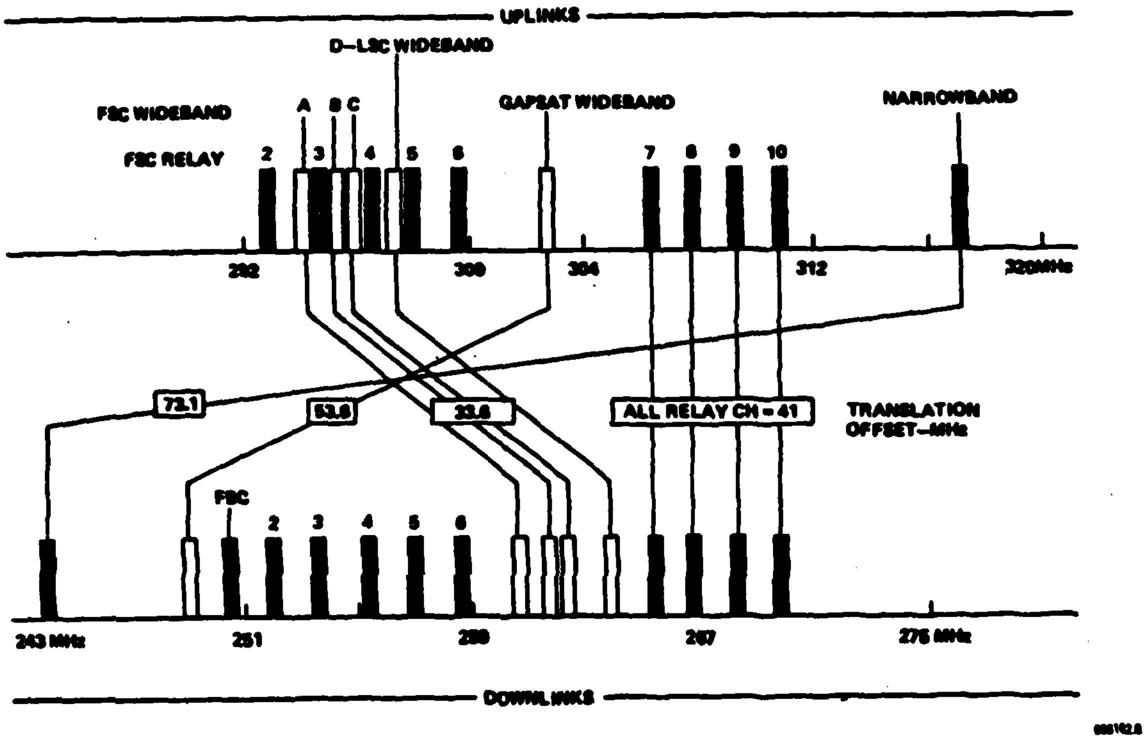
3.3 UHF Terminals

As one of the oldest forms of military SATCOM, UHF radio terminals are in abundant supply. Table 3-2 provides some estimates of the number of current and planned UHF SATCOM terminals. The Air Force envisions future requirements of about 3000 terminals. Similar requirements are estimated for the Navy, Army, and special users of the DoD

Table 3-1. Nonprocessed UHF Satellite Systems and Channel Characteristics

Satellite Type	# of Planned Orbital Locations	RF Band Up/Down	Channel BW (KHz)	No. of Chans.	Xponder Pwr(dBW)	Number of Freq. Plans.
FLTSATCOM	4	UHF/UHF	500	1	27	1 of 3
FLTSATCOM	4	UHF/UHF	25	8	26	1 of 3
FLTSATCOM	4	UHF/UHF	25	1	28	1 of 3
FLTSATCOM	4	SHF/UHF	25	1	28	1 of 3
FLTSATCOM	4	UHF/UHF	5	5	16.5	1 of 3
LEASAT	4	SHF/UHF	25	1	26	1 of 4
LEASAT	4	UHF/UHF	25	6	26	1 of 4
LEASAT	4	UHF/UHF	500	1	28	1 of 4
LEASAT	4	UHF/UHF	5	5	16.5	1 of 4
Follow-on UHF	TBD	UHF/UHF	25	≃30	26/28	TBD
Follow-on UHF	TBD	UHF/UHF	5	≃40	20	TBD

Figure 3-1. UHF Satellite Frequency Plan



Satellite Systems. The impact of retrofiting or replacing terminals can be evaluated against the tabulated quantities for the various terminals shown.

3.3.1 The Generic Terminal

Changes in requirements and technology have resulted in the development of UHF terminals with extremely diverse characteristics and operational capabilities. In order to compare these terminals, they must be divided into four terminal-element categories; source processing, waveform processing (baseband), radio (RF/IF) characteristics, and network characteristics. The generic terminal that encompasses these characteristics is defined. Figure 3-2 depicts a set of generic terminals as a point-to-point link. Each block represents data and controls in the path as the signal traverses from user 1 to user 2. Complete interoperability is achieved by each tier element being identical or complementary in electrical and/or control function. The convention to divide each element into a data and control section is used to delineate between data versus network or control functions. In some cases an arrow passes through a block element to connote that this element may or may not be present in a particular terminal. Bulk encryption and multiplexers, for instance, are not elements within manpack radio terminals but are common to the large DSCS-SHF terminals. Source and waveform processing are a convention introduced to split baseband characteristics into two categories. Source processing includes data entry peripherals and encryption. An alternate channel depicts use of other networks such as the AUTOSEVOCOM. Waveform processing encompasses multiplexing, coding, interleaving, bulk encrypting, and modulating. Other user entry points are included when the terminal supports a group rather than one user. Some terminals have elements of the baseband processing combined in one package. In these cases the equipment is described as a package. Radio characteristics include full- or half-duplex operation, tuning, translation offsets, bandwidth, EIRP, and the receive figure of merit (G/T). A channel element with thermal noise added to the up and downlinks is shown, but it is not discussed in this report.

3.3.2 Source Processing

The elements that make up source processing are the peripheral interface between the user and the system and the encryption of the source data. The three primary peripheral devices are voice digitizers, teletype, and facsimile. Voice digitizing widely varies among the services. A small subset of voice compatibility exists with FM voice, but this

Table 3-2. Estimated UHF/SHF SATCOM Terminal Deployment

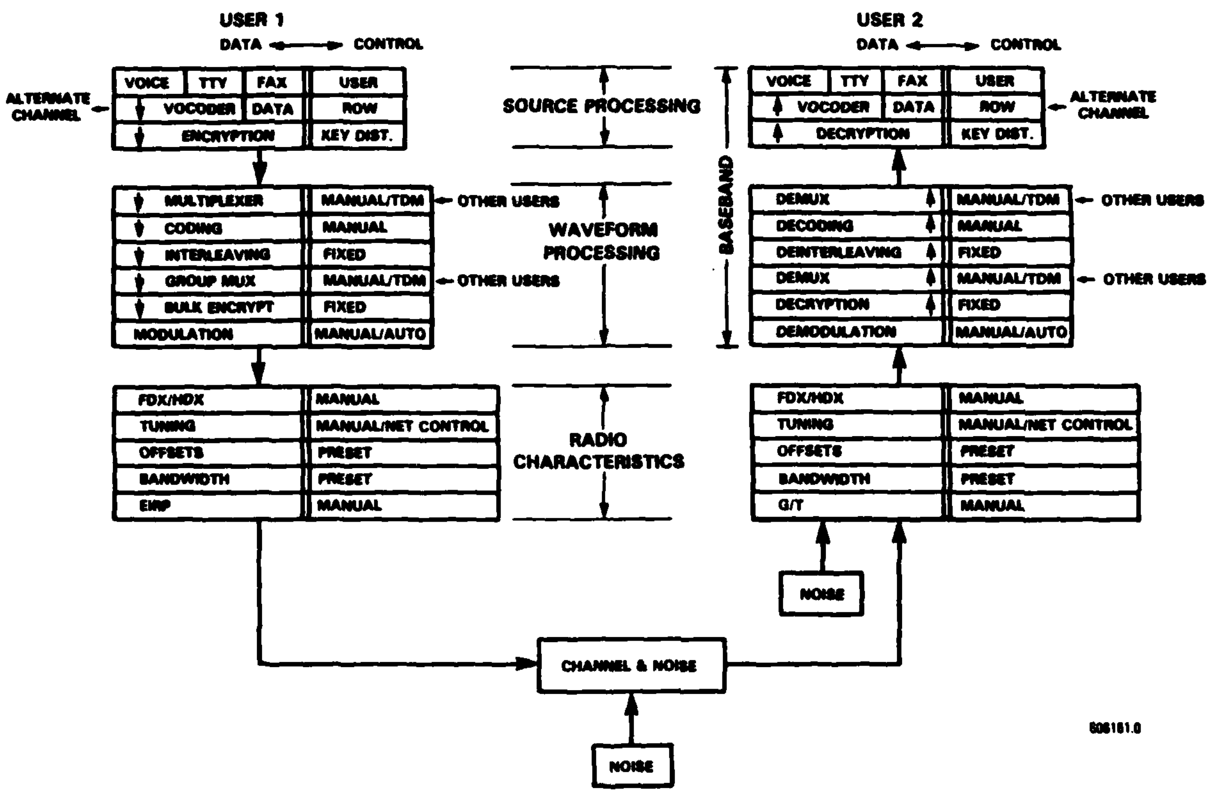
Terminal	Current use	Future use	User Group
		Navy Terminals	
AN/SSR-1	582	679	FBS; 15 x 75 bps TTY (recv. only)
AN/WSC 3,5	140	162	SSIXS
AN/WSC 3,5	50	92	TACTINTEL[2]
AN/WSC 3,5	255	359	OTCIXS[3]
AN/WSC 3,5	400	445	CUDIX[4]
subtotal	1427	1645	
		Air Force Terminals	
AN/ASC-19	375	856	E-4 Platform
AN/ASC-21	65(29)	68(29)	Airborne Command Posts
AN/GSC-42	32	36	SWCP/SLFCS
AN/GSC-43,44	13	13	Consolidated Gnd. Term.
AN/USC-39	5(7)	53(7)	Quick Response Terminal
AN/FRC-175	45(164)	102(175)	Land Control Center
AN/TSC-102	11	11	Mobile Tactical Battlefield
MAC MUST	0	333	KC-135R
MX-800	0	101	USAF Contingency
MX-850	119	119	USAF Contingency
AN/FSC-82	5	5	Tactical Gateway for TSC-102
AN/WSC-3(V)9	8	8	Tactical Gateways
AN/TSC-88	4	4	Contingency Terminals
subtotal	682(767)	1709(1697)	
		Army Terminals	
AN/PSC-3	≃700-900	≃700-900	Digital Msg. Entry Device
AN/TSC-91	1	1	CP Terminal (replaced by MSC-64)
AN/TSC-92	23	23	FE Terminal (replaced by MSC-64)
AN/TSC-99	12	12	S-280 Mounted
AN/VSC-7	35	35	Vehicular PSC-3
subtotal	≃700-981	≃700-981	
		Joint Terminals	
AN/GSC-40	7(4)	7(4)	Ground Command Post (USA/USAF/NAVEUR)
MSC-64	152(210)	(330)	Theater Nuclear Forces (USA/USAF-processed)
AN/URC-101	≃600-1000	≃600-1000	Joint USA, USAF, USN (25 kHz)
AN/URC-110	≃100	≃100	Joint USA, USAF, USN (LPC-10/5 kHz)
AN/URC-112	4	4	Joint (URC-110) + extra band (discontinued)
subtotal	297(352)	475(472)	
Total	3968(4108)	5993(5978)	

Notes

Current and Future use (CY):	Current	Future
USN	1982	1990
USAF	1982	1988
USA	1982	1988

1	Upgrade CV3333/U with ANDVT spec.
2	23 Network members max.
3	Officer and Tactical Command High speed TTY (2.4 kbps)
4	10 x 2.4 kbps or 50 x 75bps TTY
( )	difference in numbers varied with reference first # Ref. 18, (bracketed #) Ref. 12 (USAF; Hq. AFCC/XPQCC)
?	figure unknown

Figure 3-2. Diagram of the Generic Tactical Radio System



application is normally used for dedicated channel LOS applications. Table 3-3 summarizes the source processing characteristics of the terminals for the special users and services. This table presents types of terminals and data rates and identifies whether they support voice, teletype, and facsimile data entry equipment. Table 3-4 details the source processing equipment according to the services.

3.3.2.1 Teletype and Voice Interface

Teletype equipments have two types common of character sets (ASCII and Baudot), four word sizes (5-, 6-, 7-, and 8-bit), and various data rates (75 bps to 9.6 kbps). Joint service equipment has the highest level of compatibility because it supports modes that can interoperate with all of the services' equipments.

Voice interface peripherals may be analog or digital. Analog modulators may use frequency (FM) or amplitude (AM) modulation. Typical applications use FM for satellite links and AM for LOS application. Voice digitizing algorithms include continuously variable slope delta modulation (CVSD), linear predictive coding (LPC), pulse code modulation (PCM), or a variation of these algorithms. Data rates and voice quality vary as to the method used (see section 4.1.4).

3.3.2.2 Encryption

Encryption equipment must have two compatible elements in order to interoperate. These are the encryption algorithm and the capability to provide the same key variable. Manually loaded or electrically loaded keys variables are used to synchronize the encryption between the transmitter and receiver. Encryption equipment may be configured in two ways. Basic end-to-end encryption uses encryptor devices on a user-to-user basis typical of manpack terminals. Multiplexing may be used to aggregate circuits into the link data rate prior to link encryption. Bulk encryption aggregates links prior to encryption, especially in terminals used for Army tactical gateways. Combinations of end-to-end and link encryption define double encryption such as the type sometimes used by wideband Navy AUTOSEVOCOM. DoD organizations use a variety of A/D-encryption devices, and Table 3-6 lists the types important to the tactical community. Devices that are normally paired to perform multiple functions are underlined along with their components. Of the devices listed, the KG-30 series (KG-30 through KG-39) encryptors all interoperate with one another. This feature is attractive when viewing the "AUTO" networks described in the gateway section. The Secure Telephone

Table 3-3. UHF SATCOM Source Processing Terminal Characteristics

Terminal Type [USER†]	Data Rate (kbps)	Digital Voice	Tele-type	US Service
ARA-169 [N]	?	?		TACAMO Air
ARC-138 [N]	?	?		TACAMO radio
ARC-143B [N]	?	?		P-3C
ARC-146 [F]	9.6	?		ARIA Pres.
ARC-156 [N]	?	?		S-3A fltops
ARC-164	?	?		small radio
ARC-171 [F]	.075	yes	x	5 kHz SATCOM radio
ARC-178(V)	?	?		Airborne URC-93
ARC-182 [N]	2.4	?		Navy Airborne
ARC-182-II [N]	2.4	?		Navy CY-1989
ASC-19 [F]	.075	?		Airborne/SAC SIOP
ASC-21 [F]	.075	?		WWMCCS/CINCNET
AN/FRC-175 [F]	.075	no	x	Minuteman
FSC-82 [F]	A,16.	yes	x	Tactical gateway
GSC-40 [J]	.075	?		TNFGCP AFSAT
GSC-42(V)1-5 [F]	.075	no	x	SWCP
GSC-43,44 [J]	.075	no	x	gnd. CP/WWMCCS
HST-4 [A]	E,?	yes	x	Commercial PSC-3
LSR-420	A	yes	x	Portable AFSAT
LST-5 [S]	?	yes		in production
LST-5A [S]	D	yes		in production
LST-5B [F,S]	1.2,2.4,16	yes	x	in production
MSC-64 [A,F]	.075	?	x	GMF-AFSAT
MSC-64(V)4 [A,F]	.075	?	x	AFSAT/FLTSAT/DAMA
MSC-71 [N]	?	?		MATNET test term.
MX-800 [F]	?	?		AFSAT Contingency
MX-850 [F]	Analog	yes		portable
AN/PSC-3 [J]	E	yes	x	GMF Manpack
AN/PSC-3(A) [A]	F	yes	x	GMF Manpack
AN/PSC-3(V)1 [A]	F	yes	x	GMF Manpack
PT-25A [A]	none	yes		GMF Manpack
SSR-1 [N]	1.2	no		FBS Recv.
TRC-157 [F]	9.6	yes		USAF WHCA Manpack
TSC-88 [F]	.075	no		AF ground cmd. post
TSC-99 [M]	A	yes		USMC van; 3-WSC 3's
TSC-91,92 [A]	.075	no	x	old FE AFSAT NWS
TSC-101/2 [A]	A,16	yes	x	GMF Crisis Mgmt.truck
AN/USC-37 [J]	.075	yes		Force elm./secure
AN/USC-39 [F]	.075, 2.4	yes		Force elm./secure
AN/URC-93 [N]	?	yes	x	USN gen. radio
AN/URC-100 [A]	D	?	x	Portable SATCOM ???
AN/URC-101 [J]	D	?	x	Portable SATCOM
AN/URC-104 [S]	D	?	x	Portable SATCOM
AN/URC-108 [F]	A,16.	yes	x	Portable SATCOM
AN/URC-110 [J]	D	LPC-10	?	ANDVT
AN/URC-112 [J]	2.4	LPC-10	?	URC-110+extra band
VSC-7 [A,F]	F,16.	yes	x	GMF Jeep mount
VSC-7(A) [A,F]	F,16.	yes	x	GMF Jeep mount
AN/WSC-3(V) [N]	A	yes	x	USN std. ship
AN/WSC-3(V)9 [F]	B	yes	x	Tactical Gateway
AN/WSC-5(V) [N]	C	yes	x	USN Shore Station

Notes

† [A] = USA, [F] = USAF, [M] = USMC, [N] = USN,
[S] = Special Forces/Intelligence, [J] = Joint Service use

A 75, 300, 600, 900, 2,400, 4,800, and 9,600 bps

B PSK - rates like A with OM-43 modem; AM/FM at 2400 bps, FSK at 75 bps

C same as B; Full (2 circuits) or half duplex operation; six circuits

D 300, 1200, 2400 with PM-15A; BPSK,DBPSK @300bps,1200bps SBPSK@2400bps.

E 300, 1200 ?, 2400

F 300, 1200, 2400

Table 3-4. Baseband Characteristics for Tactical SATCOM

Navy Baseband Equipment

Analog (A)/ Digital (D)	Voice (V)/ Data (D)	Encryption	Data Rate bps/[bw]	Bits/ Char.
A - FM	V	KY-65 PARKHILL	[16kHz]	n/a
A - FM	V	KY-3	[500kHz]	n/a
D - CV3333/U	V	KY-57,8 VINSON	2.4 K	n/a
D - CV3333/U	V	KG-13,KG34	2.4 K	n/a
D -TTY (note 5)	D	KG-34	75-9.6Kbps	6
D -TTY (note 6)	D	KG-34	75-9.6Kbps	5

Air Force Baseband Equipment

Analog (A)/ Digital (D)	Voice (V)/ Data (D)	Encryption	Data Rate bps/[bw]	Bits/ Char.
D -TTY(ASCII)	D	KG-35	75-300	8
D - CV3333/U	V	KY-57,8 VINSON	2.4 K	n/a
D - CV3333/U	V	KG-13,KG34	2.4 K	n/a
A	V	KYV-2B	[16 kHz]	n/a

Army Baseband Equipment {note 4}

Analog (A)/ Digital (D)	Voice (V)/ Data (D)	Encryption	Data Rate bps/[bw]	Bits/ Char.
D-TTY(ASCII)	D	none	75-9.6Kbps	6,7,8
D-TTY(ASCII)	D (note 2)	KG-81	75	??
D - CV3034A/G	V (note 10)	KG-30's	note 1	n/a
D - PCM/TDM	V	KG-81	64Kbps	6

Joint Equipment

Analog (A)/ Digital (D)	Voice (V)/ Data (D)	Encryption	Data Rate bps/[bw]	Bits/ Char.
D - TTY(ASCII)	D (note 3)	KYV-5	75-2.4Kbps	??
D - LPC-10	V (note 3)	KYV-5	2.4Kbps	n/a
D - TTY	D (note 7)	KY90	??	??
D - CVSD	V (note 8)	KY68/78	16/32Kbps	??
D - CVSD	V (note 9)	n/a	16/32Kbps	??
D - FAX	D	KY68/78	16/32Kbps	??

Notes

1	48 Kbps + 2 Kbps overhead - algorithm unknown AUTOSEVOCOM
2	75 bps TTY converted to tone (VF signal) via VFCT - tone group
3	ANDVT terminal
4	Army Tactical is mostly DSCS - SHF
5	Navy TTY ASCII: model IP-1187/USQ-64(V)
6	Navy TTY Baudot: model AN/UGC-48 and AN/UGC-77
7	Joint TTY ASCII & Baudot model AN/UGC-74()(V)
8	Joint Digital Secure Voice Terminal (DSVT)
9	Joint Digital Non-secure Voice Terminal (DNVT): TA-9[illegible]4()/TT, TA-984()/TT
10	Planned plug-in upgrade to joint compatible 16/32 Kbps CVSD

Unit - II (STU-II) and STU-II/A, have common interoperation modes; however, this is not shared with the new STU-III's key distribution. STU-II series uses a Bellfield key distribution system while the STU-III uses the Firefly system.

Only one known analog encryption device is used in UHF SATCOM, the PARKHILL (KY-65/75) analog encryption device. It is widely used for perishable tactical information, and roughly 10,000 units are in service. This device uses a spectral band and time transposition of the signal to form a pseudo-secure link.

3.3.2.3 ANDVT

The ANDVT is a secure terminal capable of transmitting or receiving digital data or voice. Input data rates may vary; however, data output is fixed at 2400 bps. The intended users in the tactical community are ship, airborne, mobile, and fixed platforms. Its modular design has two basic sections: an analog voice processing section (LPC-10), and a modem section. A plug-in unit (KYV-5) provides COMSEC capabilities. The design allows five configurations to support a variety of functional capabilities. Reference 7 thoroughly details the performance specifications. These specifications allowed the module construction to be carried out at three different sites. The NAVELEX-sponsored design and development group (ITT) has produced prototypes that conform to this specification with some additional features. These features are summarized in Table 3-5. A noteworthy design feature is the detachable COMSEC device which, when removed, declassifies the terminal. Additional features added during prototype design and development that apply to UHF operation follow:

- Adaptive Noise Cancellation - An adaptive filter to attenuate acoustic platform noise which can remove background noise such as the sounds of a helicopter rotor.
- Automatic Gain Control - AGC is provided for analog speech input so a wide range of audio input levels can be used.

3.3.2.4 STU III

STU III terminals are secure voice digital telephones that may interface over normal half-duplex telephone lines in a secure or nonsecure mode. Some versions can be used full duplex in conjunction with command/control terminals (AUTOVON [Motorola]). The voice digitizer is LPC-10 at a 2.4-kbps data rate with BER of 10^{-5}. Manufacturer variations include echo cancelling, 4.8-kbps data rate, and half- or full-duplex operation.

Table 3-5. Standard Features of the ANDVT

	USER INPUT					PROTOCOL		CHANNEL OUTPUT					
APPLICATION #	AUDIO VOICE	DIGITAL DATA @ 2400 bps	DIGITAL DATA @ 1200, 600, 300 bps	DIGITAL VOICE @ 2400 bps	DIGITAL SIGNALS 128-bit BLOCKS @ ~152 bps	NET	POINT-TO-POINT	SECURE	HF MODULATION @ 2467 bps	HF MODULATION @ 2400 bps	LOS MODULATION @ 2400 bps	DIGITAL VOICE @ 2400 bps	DIGITAL DATA @ 2400 bps
1	■					■	■	■	■				
	■					■		■			■		
2		■				■		■		■	■		
			■			■		■		■			
				■		■	■	■	■				
				■		■		■			■		
					■	■		■		■	■		
3	■					■		■				■	
		■				■		■					■
4	■					■						■	
5		■				■				■	■		
			■			■				■			
				■		■			■		■		

Table 3-6 details encryption and vocoder devices and which services use them.

3.3.3 Waveform Processing

Waveform processing (see Figure 3-2) includes two forms of multiplexing; time division and/or frequency division (group) multiplexing, coding, interleaving, and bulk encryption. Group multiplexing and bulk encryption are used by the Army SHF terminals; however, these components can be avoided by using alternate channels (i.e., AUTOSEVOCOM/AUTODIN/AUTOVON). Coding and interleaving elements may or may not be applied to processing the data but modulation is mandatory.

3.3.3.1 Coding

Coding schemes for UHF SATCOM terminals have three selectable methods. They are uncoded, convolutional rate 1/2, and rate 3/4. Implementation may vary as different electrical circuits may or may not be used to implement rate 3/4 from punctured rate 1/2 coding. Punctured coding is planned for use by the Air Force. Although this results in a simpler hardware implementation, the resulting rate 3/4 is not compatible with the existing rate 3/4 code used by the Navy's TDMA-1.

3.3.3.2 Modulation

Modulation normally needs to be identical for interoperability. However, MSK and OQPSK or SBPSK and BPSK may interoperate with a degraded level of performance. This performance loss is determined by the match between the transmitter and receiver waveform filters. UHF terminals support a wide variety of modulation: AM, FM, FSK, BSPK, SBPSK, DBPSK, QPSK, OQPSK, and PSK. Selected interoperation standards call for modems to use SBPSK. Modems using SBPSK also support differential BPSK. Performance on the UHF follow-on satellite will be more sensitive to modulation techniques due to higher transmission rates, DAMA, and the closer channel spacing. Reference 18 points out that a difference in modulation techniques between adjacent channels (i.e., BFSK and SBPSK) could cause unacceptable levels of ACI. With design plans for SPBSK, BFSK, and OQPSK on the 5-kHz channels with 5-kHz centers, this is a key issue and is addressed under another subtask of this contract.

Table 3-6. Encryption-A/D Devices

Device Type[Quantity]	Device Function	Used by DoD Organization
ANDVT(3591)[100]	LPC-10,M	Joint
KYV-5	E	Joint
CV-3333/U	16kbps CVSD	USN (WSC-3,5)
CV-3034	50kbps PCM(6-bit)	USA
STU-2,KY-71[3,000]	LPC-10,E,KG,M	Joint
STU-2/A,KY-71	Sec. Voice,E,M	AUTOSEVOCOM upgrade
STU-III,KY-72	Sec. Voice,E,M	Joint
TSP Series 4000	LPC-10/LPC+ 2.4 kbps	Joint
TSP Series 2700	LPC-10/LPC+ 2.4 kbps	Joint Airborne Ver.
KG-30[10,000[1]]	Secure Voice/Data	Cmd. Post to Cmd Post (USAF)
KG-33/34	Secure Voice/Data	Full duplex AFSATCOM-SIOP
KG-13/34	Secure Voice/Date	AUTOVON
KG-35/36	Secure Voice/Data	Half duplex USAF (ARC-171)
KG-84[100,000]	Secure Voice	DDN/USAF
KGV-11	Cntl Orderwire	USN/USAF
KN-2	75 Bps Data	USA,USAFE,NAVEUR,CINCPAC (GSC-40) Tri-modem TDM3 (short preamble)
KW-7	Tactical TTY-28/40	AUTODIN
KY-3	Secure Voice	AUTOSEVOCOM Analog (WB)
KY-57/58	VINSON	USAF (ARC-164,182, WSC-3,), USA (PSC-3)
KY-65,75[10,000]	PARKHILL(Analog)	Joint
KYV-2	CVSD,KG	USAF

KEY

E - Encryption

M - Modem

KG- Key Generator

1 - quantity for all KG-30 series (KG-30 - KG-39)

3.4 RF/IF Equipment

Primary RF parameters for terminal interoperability must have satellite compatible elements for frequency range-tunability-offsets, transmit power (EIRP), receive figure of merit (G/T), and limited adjacent channel interference. Tabular values for these items (except offsets) may be found in Table 3-7 and Reference 18. Tunability and frequency offsets are major RF concerns as reception is impossible or degraded without frequency alignment. UHF frequency allocation is carefully planned to ensure a minimal amount of overlap in frequencies between the services. Typical 25-kHz channel radios, for instance, can discretely tune 7000 individual channels. Transmit frequencies are paired with receiver frequencies to establish a unique uplink/downlink frequency plan. The downlink receive frequency is supplied by an offset mechanism built into the radio. Depending on satellite characteristics, the transmit frequencies are translated to unique receive frequencies; hence, the need for adjusting receive offsets is imperative for proper satellite operation (see Figure 3-1.). Terminal EIRP and G/T determine if the radio has the capability to establish the uplink and downlink, respectively. In the follow-on UHF planning there is recognized potential for channel interference. This satellite problem arises from the closer channel spacings, unbalanced received signal from manually controlled terminal EIRP, and the increased number of intermodulation products. Radio-frequency-induced adjacent channel interference (ACI) is caused by relative channel EIRP and modulation technique.

Intermediate frequency is a terminal interoperability issue when modems supply an IF data interface into the transmit/receive stream. By standardization most intermediate frequencies are 70 or 700 MHz; however, some popular UHF SATCOM terminals provide a different IF interface.

3.5 UHF MILSATCOM Networks

DoD organizations use a variety of network protocols for UHF communication Networks range from dedicated single-channel users to TDMA systems. This section presents the current network protocols and proposed TDMA/DAMA systems. Of the existing systems, the most structured UHF networks are used by the Navy. Many Navy networks are relatively fixed in application and once configured remain in place. Air Force platforms are subject to rapid activation and deactivation with bursty communications. Structure diminishes to single-channel users where the environment may be FDMA equipment and resource allocation is performed by end-point users.

Table 3-7. UHF SATCOM Terminal Radio Characteristics

Terminal Type [USER†]	Tunea-bility (kHz)	EIRP (dBw)	G/T (dBw)	US Service
ARA-169 [N]	?	26	?	TACAMO Air
ARC-138 [N]	?	26	?	TACAMO radio
ARC-143B [N]	?	26	?	P-3C
ARC-146 [F]	?	?	?	ARIA Pres.
ARC-156 [N]	?	23	?	S-3A fltops
ARC-164	?	?	?	small radio
ARC-171 [F]	25	?	?	5 kHz SATCOM radio
ARC-178(V)	?	?	?	Airborne URC-93
ARC-182 [N]	5	?	?	Navy Airborne
ARC-182-II [N]	1	?	?	Navy CY-1989
ASC-19 [F]	5	18	-30	Airborne/SAC SIOP
ASC-21 [F]	?	17-27	?	WWMCCS/CINCNET
AN/FRC-175 [F]	?	27.	-33	Minuteman
FSC-82 [F]	5/25	18-28	-20,-22	Tactical gateway
GSC-40 [J]	?	22-29	-20	TNFGCP AFSAT
GSC-42(V)1-5 [F]	?	24-31	-18,-27	SWCP
GSC-43,44 [J]	5	19-31	-26,-27	gnd. CP/WWMCCS
HST-4 [A]	5	17.8	?	Commercial PSC-3
LSR-420	5	20	?	Portable AFSAT
LST-5 [S]	25	19.	?	in production
LST-5A [S]	25	19.	?	in production
LST-5B [S]	5/25	18-21	-22.4	in production
MSC-64 [A,F]	?	28.	-21.	GMF-AFSAT
MSC-64(V)4 [A,F]	?	28.	-21.	AFSAT/FLTSAT/DAMA
MSC-71 [N]	?	?	?	MATNET test term.
MX-800 [F]	25	14.8	-28.6	AFSAT Contingency
MX-850 [F]	25	19.	-16.7	portable
AN/PSC-3 [J]	5	21.5	-23	GMF Manpack
AN/PSC-3(A) [A]	5	20.5	?	GMF Manpack
AN/PSC-3(V)1 [A]	5	20.5	?	GMF Manpack
PT-25A [A]	25	7.	-23	GMF Manpack
SSR-1 [N]	1	N/A	-30	FBS Recv.
TRC-157 [F]	?	?	?	USAF WHCA Manpack
TSC-88 [F]	?	17-27	-16,-17	AF ground cmd post
TSC-99 [M]	?	23	-22	USMC van; 3-WSC 3's
TSC-91,92 [A]	?	17-26	-14,-30	old FE AFSAT NWS
TSC-101/2 [A]	5/25	18-32	-18,-24	GMF Crisis Mgmt.truck
AN/USC-37 [J]	5	26	-25	Force elm./secure
AN/USC-39 [F]	?	26	-25	Force elm./secure
AN/URC-93 [N]	?	?	?	USN gen. radio
AN/URC-100 [A]	25	13.	?	Portable SATCOM
AN/URC-101 [J]	25	20.	-24.	Portable SATCOM
AN/URC-104 [S]	25	19.	?	Portable SATCOM
AN/URC-108 [F]	25	20-25	-23.	Portable SATCOM
AN/URC-110 [J]	5	13-20	-24.	ANDVT
AN/URC-112 [J]	25	19-20	-24.	URC-110+extra band
VSC-7 [A]	5	18-23.5	-22.	GMF Jeep mount
VSC-7(A) [A]	5	18-23.5	?	GMF Jeep mount
AN/WSC-3(V) [N]	5	24-30	-18	USN std. ship
AN/WSC-3(V)9 [F]	5	24-30	-18	Tactical Gateway
AN/WSC-5(V) [N]	50/25	27	-12	USN Shore Station

Notes

† [A] = USA, [N] = USN, [F] = USAF, [M] = USMC,
[S] = Special Forces/Intelligence, [J] = Joint Service use

1 1 of 6 crystal tuned channels

3.5.1 Navy Protocols

While all the armed forces use UHF satellite terminals, the U.S. Navy has the largest segment of operational networks. The seven major subsystems that encompass the Navy UHF are the Fleet Broadcast System (FBS), the Common User Digital Information Exchange Subsystem (CUDIXS)/Naval Modular Automated Communications System (NAVMACS), the Submarine Satellite Informations Exchange Subsystem (SSIXS), the Officer-in-Tactical-Command Information Exchange System (OTCIXS), the Secure Voice Subsystem, the Tactical Intelligence Subsystem (TACINTEL), and a Control Subsystem. These systems are being modified to operate in a fixed time slot within the TDMA/DAMA protocol as described in Reference 4. The basic structure is a TDMA protocol with a network controller capability to assign/deassign user slots one per frame. One forward and return orderwire exists to manage a manual resource allocation process.

3.5.2 Air Force Protocols

The Air Force uses two basic modes of network protocol for AFSATCOM: ASFAT I and AFSAT II. AFSAT I uses binary frequency shift keying (BFSK), and AFSAT II uses 8-ary multiple frequency shift keying (MFSK) with channel hopping. AFSAT I supports three frame protocols: TDM-1, TDM-2, and random. A modem-provided optional mode supports 75- and 1200-bps phase shift keying (PSK) for reception of the Fleet Broadcast Receive. TDM-1 and 2 both have 60 equal-time duration slots partitioned in each frame with the last slot permanently assigned to the channel controller. TDM-1 has three operational modes. A random mode allows users to scan the allocated frequencies for an unused channel by monitoring channel activity. In this mode a time-out is imposed on channel assignment if the user is inactive. This is a distributed form of network control. A second mode is under command post control where polling/response is used. Command posts broadcast a polling message which all force elements decode. If the force element decodes its unique address, it responds with a transmission to the command post. These protocols are applied to both narrowband and wideband channels. TDM-2 grants slots to users using the orderwire slot whereas TDM-1 slots are typically preassigned on a mission basis. AFSAT II uses time and frequency division multiple access protocols. They are used for both stressed and nonstressed environments. The details of the third method are classified; hence, they are not discussed in this report.

3.6 Proposed Multiple Access Techniques

A major thrust in UHF interoperability efforts is to relieve overburdened satellite capacity by using channel time and frequency sharing methods. A popular technique pursued by many organizations is a TDMA/DAMA protocol. This method divides a fixed or variable frame length into three basic slots:

- Radio Synchronization - Ranging, doppler shifting, acquisition, etc.
- Orderwire - Forward (FOW) and return (ROW) control user requests and controller grants of satellite use.
- Data - *User communication traffic*

Techniques are under development to optimize system throughput against such factors as priority, requests, and current channel loading. The object is to obtain a system that can dynamically and automatically adapt to the current environment and requires no man-machine intervention. While the following paragraphs which discuss the organizations involved in developing UHF TDMA/DAMA are by no means complete, they represent some of the work in this area. As current product line development, many organizations view this subject as proprietary material; hence, this section is incomplete.

3.6.1 Basic 5-kHz TDMA/DAMA Frame Structure

MITRE presents basic design functions that are representative of Air Force requirements for a TDMA/DAMA system in Reference 9. This document overviews the basic functions of the central controller and user terminals necessary or desirable in a TDMA/DAMA system. The basic control features are shared among the central controller and user terminals. The central controller functions are to receive and grant terminal requests on a priority basis. User terminals should have an automatic means to issue requests and take assignments. Central controller orderwires (FOW) should be full duplex and user terminal orderwires (ROW) should be half duplex. The number of ROWs will be proportional to the current state of message traffic. Control function should be coherent in that resources will be requested, granted, and returned back to the system automatically. A desirable feature is to break voice channels every 3 minutes and to have user terminals rerequest the resource from the central controller. Each channel is to have a functionally separate controller. Interfaces should also be provided into the Defense Data Network (DDN), commercial land lines, and access to adjacent UHF satellite usage.

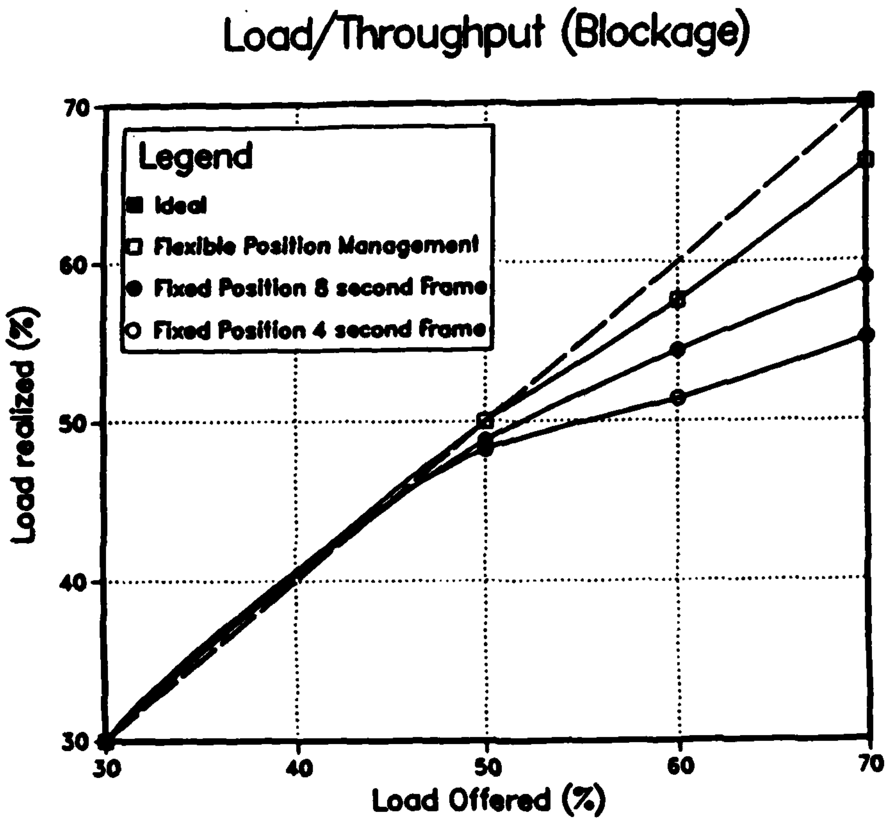
3.6.2 The J-DAMA Scheduler

Qualcomm has prepared an interoperability study for the JTC^{3}A (Reference 15) as a TA/CE for USCINCLANT ROC 5-84 requirements. It has defined a Joint-DAMA (J-DAMA) approach that claims frame structure consistency with both Air Force and Navy modems. Basic J-DAMA structure is superimposed onto developing service modems. The Navy's TD-1271 B/U modem was used as an example. J-DAMA terminals exercise control function over TD-1271 B/U modems by completely emulating their 5- and 25-kHz waveforms. Frame lengths are kept identical to the TD-1271 B/U except for the TDMA-5 configuration. Channel assignments allow for standard TD-1271 B/U formats while remaining segments are used for J-DAMA users. J-DAMA features short preambles and guard times as frequency uncertainty is corrected prior to user transmission. Other features include interleaving user slots in one frame and broadcasting a "slot busy" bit to aid the J-DAMA controllers in scheduling.

3.6.3 The Flexible Frame Scheduler

M/A-COM's flexible frame protocol is based on design and implementation methods that can be tuned by parametric sensitivity. The flexible frame system is based on elementary time segments or building blocks. An integer number of these blocks is used to construct FOW, ROW, and traffic slots. Parameters for the building block size may be adjusted to the configuration needs of the system. Three design features of the flexible-frame system are the control algorithm, control in an interrupted environment (synchronization loss), and responsiveness to dynamic traffic loading. The control algorithm has four basic functions to accommodate: priority, collision overhead, traffic slots, and request slots. Adjustments to these parameters are done on a frame-by-frame basis. Figure 3-3 highlights the flexible frame performance with respect to ideal and fixed frame scheduling algorithms. Load is defined as the number of user bits divided by the number of bits at the slew rate capacity of the channel. Load offered is the queued amount of traffic. Load realized is the amount of offered load that the channel passes. One can observe that the flexible frame scheduler performs closest to the ideal load. Details of the capabilities and configuration setup are in Reference 16.

Figure 3-3. Load Vs. Throughput Blockage



3.7 Gateways

While several thousand UHF terminals are planned for follow-on UHF SATCOM use, only a small percentage of this number needs to interoperate with diverse terminals. Likely scenarios for high priority/interoperability include Vietnam- and Grenada-type tactical force, where terminal usage is hard to characterize. The majority of UHF terminals most likely to serve these forces will be the AN/WSC-3,-5s, AN/URC-100 series, the AN/PSC-3, and the ARC-100 series. A common feature among them is that the fielded models will interoperate only with some retrofit to the basic unit. Such modifications may cost more than replacing the entire unit.

If the scope of interoperability is to include dissimilar point-to-point users, then gateways would be a practical way to implement them. This section will demonstrate that the near-term inclusion of gateways for interoperation has no technical or logistic impact since worldwide site installations for all the services are in place and in use. Mid- and far-term technical considerations have realistic goals that mesh with the ever increasing UHF terminal diversity problem.

The following sections present the technical and managerial considerations necessary to implement this form of interoperation. Considerations applicable to both gateway or single hop terminals are presented in the analysis chapter.

3.7.1 Pros and Cons of Gateways

Gateways serve to translate one network protocol into another network protocol while retaining the information content of the message. Such a translator usually requires two equivalent sets of terminals that have characteristics identical to the respective networks. Hardware and software to implement a gateway is inherently more complex and inefficient when compared to other links in communication networks. A summary of pros and cons follows. Negative points are:

- They require a minimum of two link hops for one message which:
  - o Increases delay time
  - o increases communication resources required
- They add to the control overhead of any network using them

- Implementing gateways requires an intimate understanding of both networks
- Digital voice data may need a human interface to relay messages

While gateways present a list of problems, they have complementary advantages in solving the interoperability problem. Some advantages are:

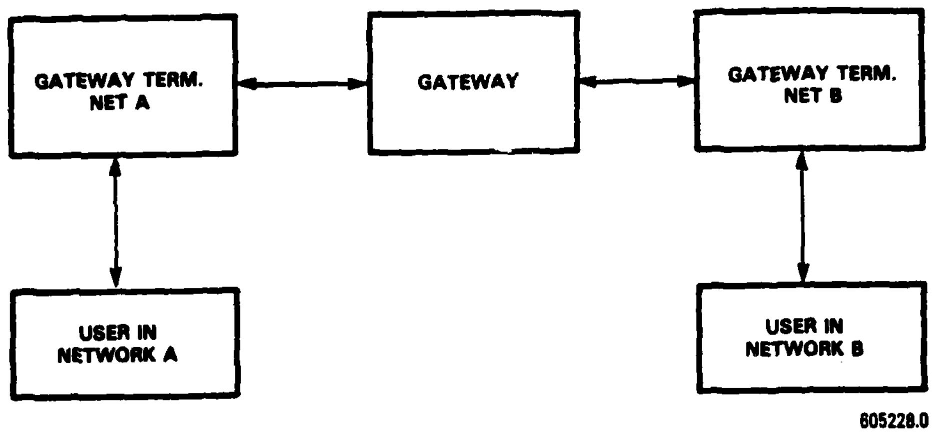
- Retrofitting the majority of terminals would be unnecessary for operation
- All the services currently have gateways into the AUTOSEVOCOM, AUTODIN, and AUTOVON networks
- Service-tailored new terminals would not make the old terminals obsolete
- The combinations of interoperable terminals would be very high

3.7.2 Basic Gateway Structure

Figure 3-4 is a simplified block diagram of two networks connected by a gateway. While gateways may be implemented in several ways, this one is for the purpose of explanation. User terminal of network A routes its data to the gateway terminal in its network. This gateway terminal decodes the message as data to a terminal in network B. It establishes the physical connection (terrestrial, satellite, line of sight, etc.) to the gateway terminal in the other network and translates the protocol into a frame format that network B uses. The data is typically passed into network B using a store-and-forward technique. Acknowledgment control is typically sent back to network A for each transmission received. The gateway performs all the protocol and data translation necessary to make these data identical to terminal B's format. Typical translation may include data, parity, checksum, and frame size/format conversions.

The physical location of the gateway may be in either network, a separate entity, or in both networks as shown in this example. Other exceptions may omit acknowledgment control and add additional backbone processors called interface message (or packet switched) processors. These processors serve to store and forward data onto proper routing links.

Figure 3-4. Block Diagram of a Gateway



3.8 Common Service Networks

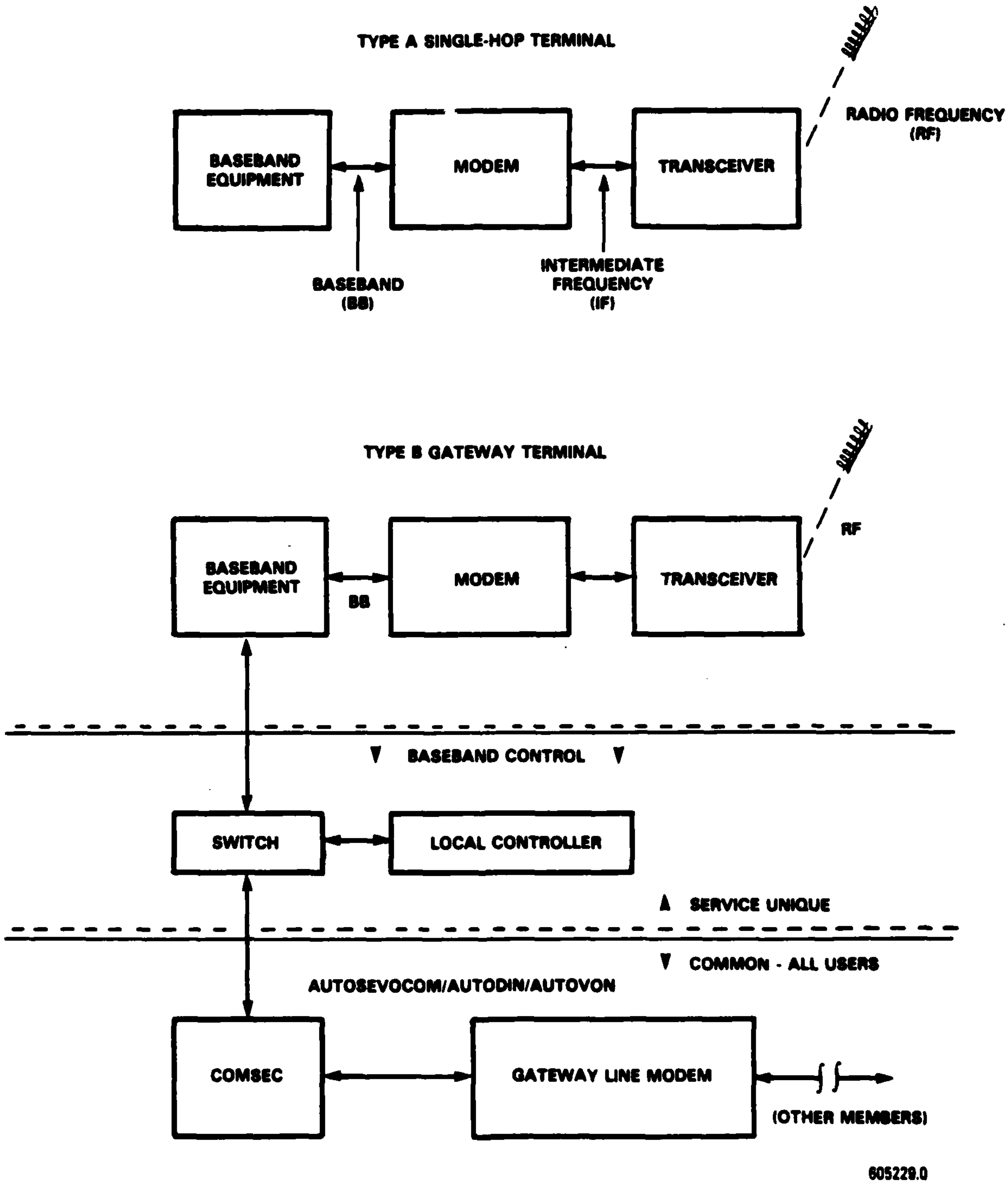
Figure 3-5 overviews the two terminal configurations used in the analysis of this report. The first element schematic (Type A) divides the terminal segment into three basic segments: baseband (BB), intermediate frequency (IF), and radio frequency (RF). A major part of this report discusses what must be compatible for some terminal of type "A" to communicate with another terminal of type "A". The second element (B) depicts a gateway terminal. This terminal is identical in function (BB, IF, and RF) to terminal type A with the inclusion of a gateway interface that can route bidirectional traffic into and out of the gateway. The schematic sections the baseband control and "AUTO" sections to stress the commonality of the "AUTO" networks. The switch and local controller of type "B" labeled "Service Unique" depicts what type of baseband data (analog, digital, clear, and secure) are under local operator control. The bottom section labeled AUTOSEVOCOM/AUTODIN/AUTOVON is common to any terminal using these networks.

The Army, Air Force, and Navy currently share common networks that use terrestrial/satellite connectivity to route traffic to other branches of their own service. The Air Force and Navy gateway terminals often share common-based RF equipment (AN/WSC-3,-5s) while the Army uses SHF SATCOM terminals (AN/TSC-85/A and AN/TSC-93/A). A DSCS gateway station or the gateway technical control facility is in every instance colocated and terrestrially linked with a nearby NAVCAMS. This section will show what UHF MILSATCOM terminals now connect into AUTOVON, AUTODIN, and AUTOSEVOCOM on a DoD organization basis. An important feature of the AUTODIN, AUTOVON, and AUTOSEVOCOM networks requires that each user implement a network-wide compatible COMSEC and line modem interface. The intent of this section is to detail the current connectivity equipment and show where gateway translators could gain interoperability with grossly different equipment. For the purpose of discussion the AUTOSEVOCOM network for all the DoD organizations will be presented.

3.8.1 Navy - NAVCOMMSTA/AUTOSEVOCOM

The Navy currently interfaces with AUTOSEVOCOM via NAVCAMS and the Naval Communications Station (NAVCOMMSTA). These shore stations use AN/WSC-5 terminals to gather 2400-bps, KG-36 encrypted, and CV-3333/U vocoded voice from AN/WSC-3 (or 3M) terminals. The shore station uses a KG-34 for decryption (clear 2400 bps) and passes the digital input into a switch that can either encrypt the digital signal via KG-13 and

Figure 3-5. Single Hop and Gateway Terminals



onto a narrowband AUTOSEVOCOM modem or recapture VF with a CV-3333/U vocoder. An audio switch board can route this signal to an analog vocoder and KY-3 crypto for entry into wideband AUTOSEVOCOM. A secure voice subsystem operator can control such operations from a secure voice console which has full AUTOSEVOCOM dialing, control, routing, audible and visual alarms, status, loopback testing, and monitoring of RF traffic. Figure 3-6 details the Navy's network AUTOSEVOCOM interface.

3.8.2 USAF AUTOSEVOCOM

The USAF has AUTOSEVOCOM network entry installations at five sites with various levels of operation. Plans called for AUTOSEVOCOM, AUTOVON, and AUTODIN service; however, implementation varied on a site basis. Four sites are within the CONUS and one is located in England. The fixed-station terminals generally employ the FCS 82 terminal with mobile TSC-102 tactical terminals. Both TSC-102 and FCS 82 terminals employ the AN/WSC-3 for their radio equipment. A typical ground station interfaces with the AUTOSEVOCOM network in a manner similar or identical to the Navy's installations. Encryption for the narrowband interface is either KY-58 (VINSON) or KY-65, the former producing the best voice quality. Wideband AUTOSEVOCOM is identical to the Navy's equipment where KY-3's are used and the voice quality is the highest. Figure 3-7 depicts the USAF's AUTOSEVOCOM interface.

3.8.3 Army - Tactical Architecture

This section is presented to expand on the Army's tactical satellite communications architecture. Army SHF tactical satellite communications (TACSAT) is based on the use of DSCS-SHF hub/spoke terminals. The AN/TSC-85A hub terminal supports one broadcast uplink to a maximum of four AN/TSC-93A spoke terminals. AN/TSC-93A terminals support one duplex link. Typical applications group-multiplex a variety of digital voice and data traffic circuits to a bulk-encrypted link whose composite bandwidth may attain 10 MHz. Network access is FDMA and PN spread spectrum using the GMF Antijam Control Modem. General guidance for the Army's architecture is proposed in the Army Space Master Plan (prepared by the Army Space Initiatives Study Group). Other tactical architecture plans include the Single Channel Objective Tactical Terminal (SCOTT) at EHF. Planned for Milstar are terminals that will provide increased protection against jammers and nuclear scintillation. The subject of this report will focus on UHF with the exception of the Army SHF terminals supporting AUTOVON and AUTOSEVOCOM systems used in

Figure 3-6. Navy/AUTOSEVOCOM Interface

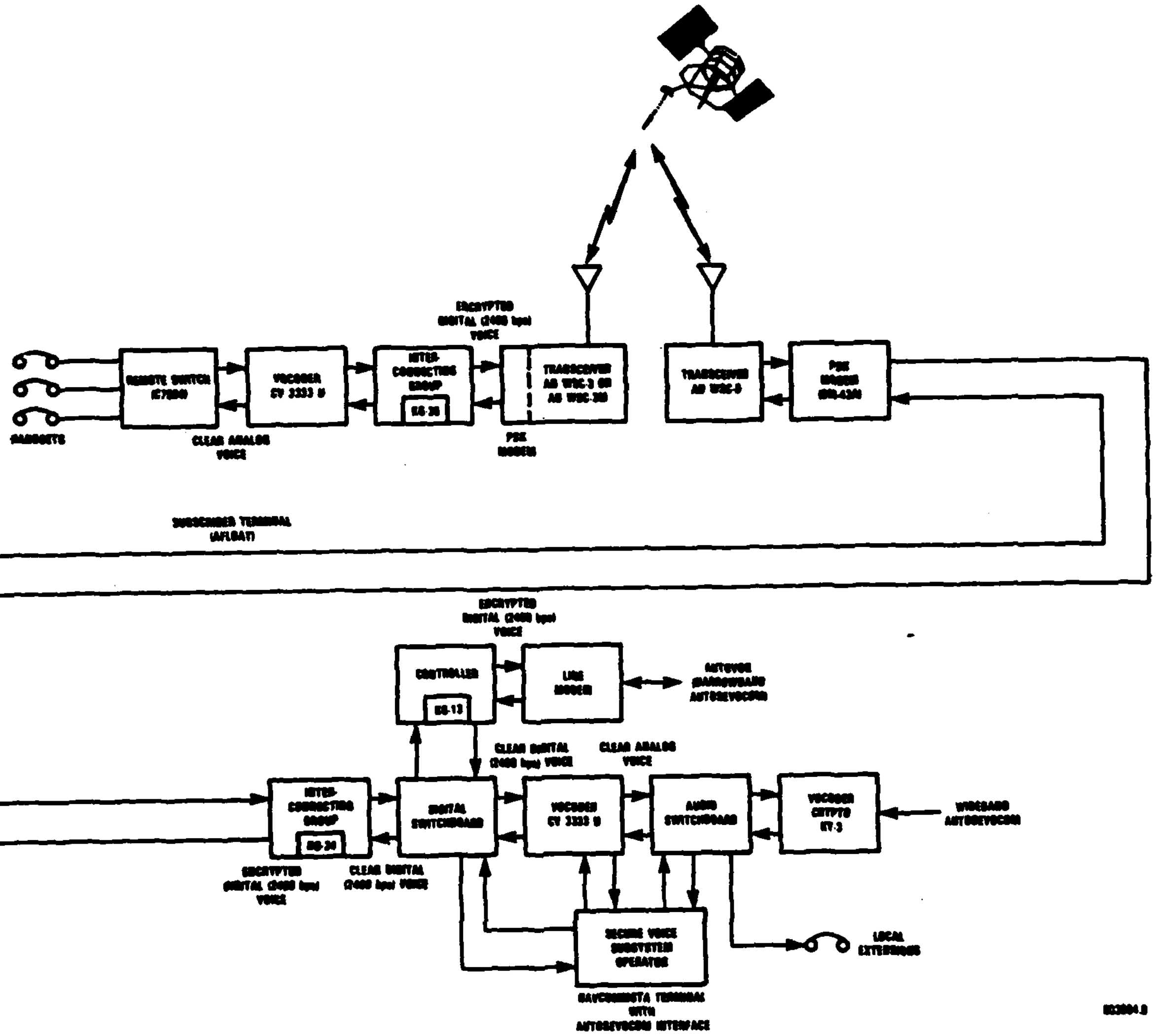
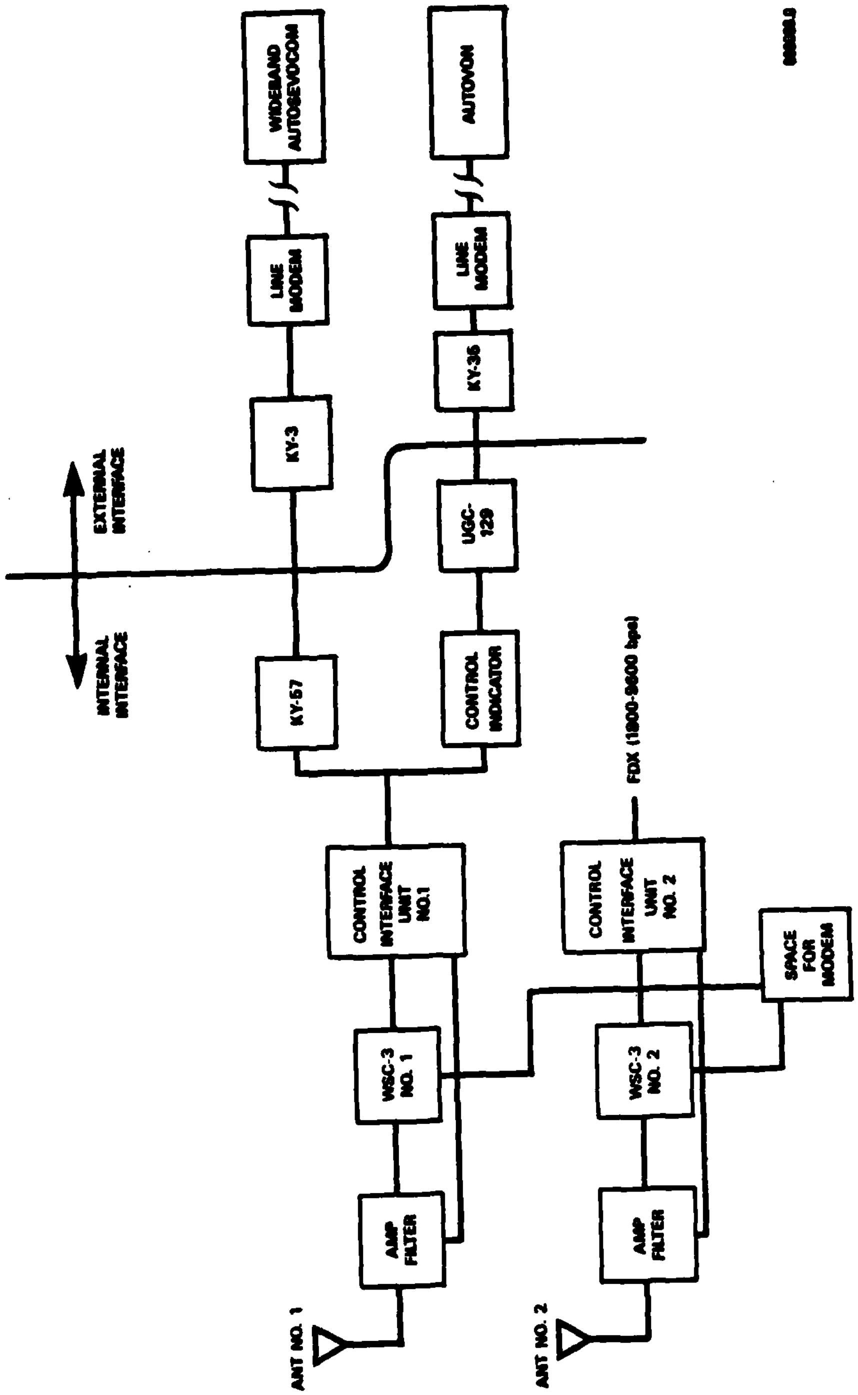


Figure 3-7. USAF/AUTOSEVOCOM Interface

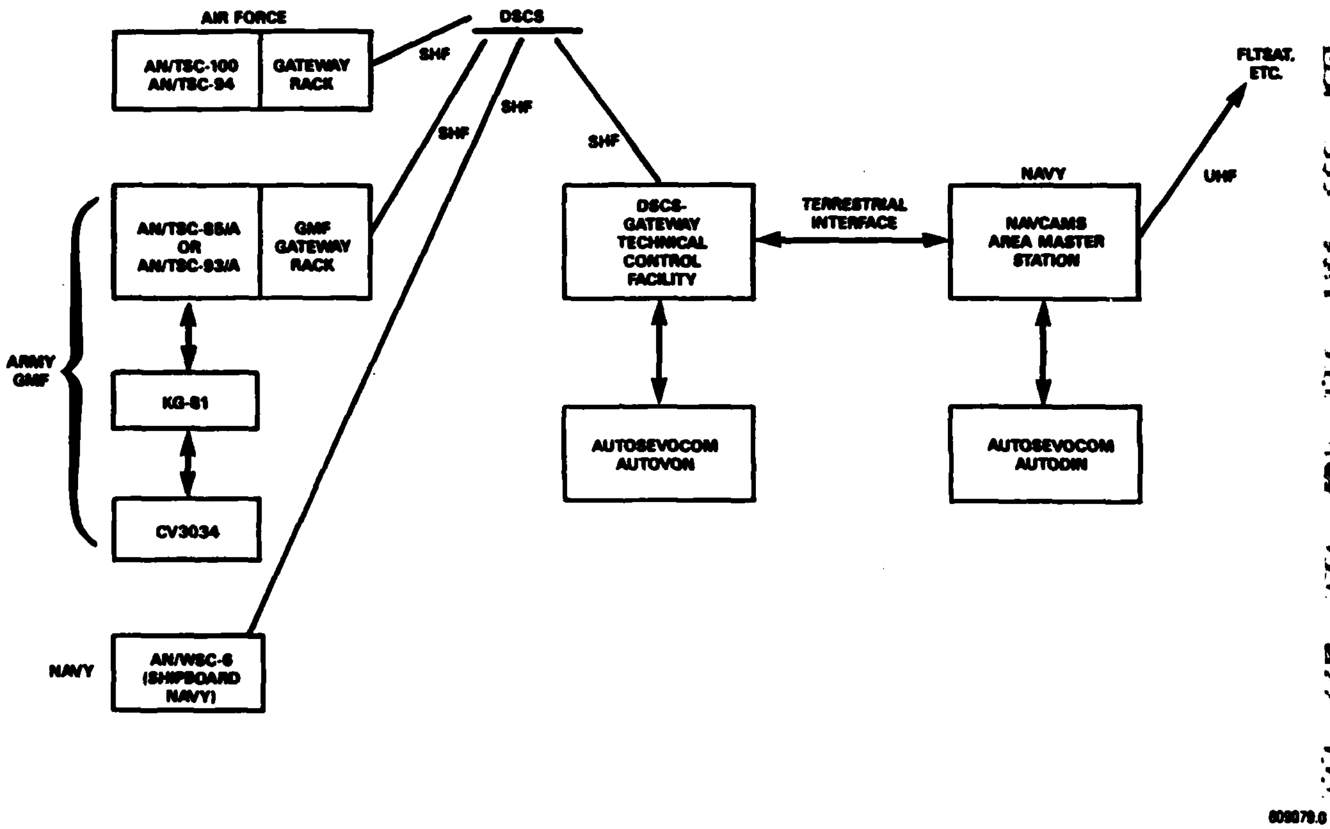


tactical Army applications. These SHF terminals are included since they offer potential interoperability via the gateway concept.

3.8.4 Army AUTOSEVOCOM

The U.S. Army normally uses SHF SATCOM tactical terminals for interconnection with the AUTOSEVOCOM network. The DSCS III, used in conjunction with AN/TSC-85A and AN/TSC-93 terminals (hub/spoke configuration), form the Army's network. As high capacity terminals they will accept clear voice (analog or digital) or digital input. Three to 24 channels can be supported from 192 kbps to 1.544 Mbps. Two types of vocoders are supported. The AN/FCC-98 voice multiplexer can support 24 full-duplex, 4-kHz analog VF circuits. Teletype and other low-speed data circuits may be interfaced to this multiplexer using a tone group (VFCT) interface. Analog data are digitized into a 64-kbps, 6-bit PCM bit stream and combined into channel groups of 3, 6, 12, or 24 channels. Output data are bulk encrypted using the VINSON KG-81. An alternative VF A/D converter is the full-duplex CV-3034. Signal sources are 4 kHz audio or a wideband switch or secure device as an AUTOSEVOCOM interface. The interface to AUTOSEVOCOM and AUTOVON networks is accomplished by using a gateway tactical terminal. A special rack mount interface provides the multiplexing, modulation, coding, etc., to patch a circuit into a Technical Control Facility. This facility provides the standard interfaces to support the AUTOSEVOCOM or AUTOVON network. Figure 3-7 shows the Army-GMF AUTOSEVOCOM and AUTOVON interface along with tri-service SHF gateway connections.

Figure 3-8. Army – GMF AUTOSEVOCOM/AUTOVON



4 Candidates for Standards

Candidates for UHF standards are varied depending on the levels of interoperability, and the near-term (NT), mid-term (MT), or far-term (FT) time frame to view the potential solutions. Many candidates are available because most concepts used in the near-term might be extended into the mid and far-term equipment. This chapter will describe various candidates according to NT, MT, and FT criteria. Candidates from elements of the generic terminal levels discussed in the previous chapter are also discussed. NT candidates require no equipment changes. They may require changes to internal modem adjustments, procedures and/or network protocols, and tend to be inefficient in terms of SATCOM resource utilization. MT candidates require retrofitting or interfacing to existing equipment along with changes to procedures and/or network protocols. These candidates provide less cost and system impact because the design and development of such changes have been done and they are tailored to fit into system structures. FT candidates require the cost intensive solutions because they re-design ground terminals to have an interoperable mode as part of their functions and design goals stress multi-user channel allocation (i.e., DAMA protocols).

4.1 Near-Term Candidates

Four near-term candidates are described for data and voice interoperability. These candidates are inefficient in terms of channel resources; however, they present viable means to gain immediate interoperation. In almost all cases the planning/logistic stages (i.e., managerial levels) are the issues that have to be addressed because technical issues are either minor or not present.

4.1.1 NT Data

Clear, non-interleaved, 75 bps FSK teletype data is the easiest of the candidates to implement because no equipment modifications are necessary. A manual mode of operation with dedicated channel access would be necessary to synchronize AFSAT force element terminals with shipboard WSC-3 radios. WSC-3 radios, using their built-in FSK modulators can acquire synchronization in 8.3 seconds while AFSAT FSK modulators acquire in 4 character time intervals. The difference in synchronization timing would mandate a special acquisition preamble and synchronous data transmission to sustain coherent transmission from AFSAT to FLTSAT (WSC-3) terminals. Manual mode operation

of the AFSAT AN/AGC-7, the AN/UGC-120B ASR, and the AN/UGC-129 ASR teletypes generate an ASCII SYN character to maintain a continuous character stream output at 75 bps. A prevailing problem is the teletype ASCII character length where the Navy uses 7-bit and the Air Force uses 8-bit.

4.1.2 NT Voice

Near-term voice compatibility may be realized by use of clear FM over 25 kHz channels. The majority of UHF terminals that are equipped with voice FM have a modulation index between 8 and 9. Other terminals with substantially different modulation indices could be re-adjusted to obtain the 8 to 9 index. While neither candidate supports efficient satellite usage, these methods represent the lowest risk for attaining immediate interoperability. The predominant issue for these candidates is defining the manual procedures that terminal operators would use to gain access and operate the terminal under these conditions.

Both candidates (NT data and voice) would require encryption to implement a secure link. Teletype data could implement a code book similar or identical to current AFSAT procedures, or the KG-30 series encryptors could be used. The KG-30 series are widespread throughout the services. The only major drawback is the long preambles necessary to synchronize this series of encryptor units. Secure analog voice can be encrypted with the KY-65/75 (PARKHILL) encryptors.

4.1.3 FBS - Simplex Relay

Another NT candidate requires a double hop in which Navy ship terminals would have their interoperable circuit relayed at shore stations using the FBS relay feature. Limited amounts of non-Navy modems have been modified and fielded that decode the Navy FBS channel. These modems can provide a simplex link between the Navy and other Navy, Air Force, or Marine services that would not normally use FBS sub-channels.

4.1.4 Near-Term Gateway Interoperation

The technical and managerial levels of gateway interoperation have desireable implementation philosophies, as stated in Chapter 1. In their current use a mix of levels 3 and 4 exist for technical considerations and level 1 for managerial considerations (See Sec 1.2). That is, the technical capability is very good, but the managerial support is

lacking. Identical components in tactical gateways such as radios, modems, and COMSEC equipment are shared between Air Force and Navy terminals. The major difference is baseband data. While some cases may be identical there can be differences such as character set (ASCII or Baudot) or data formats (see Table 3-4.). Some of the unique differences between Navy and Air Force data interleaving vanish because data is deinterleaved prior to AUTODIN or AUTOSEVOCOM entry. Near-term analysis would suggest testing such links that support the highest levels of interoperation. Such testing could be done by the NAVCAMS AUTOSEVOCOM operator dialing an Air Force rather than a Navy number. Two tables summarize the extent of worldwide gateway connectivity. Table 4-1 depicts the number and type of AUTOSEVOCOM terminals that each service currently uses and Table 4-2 lists the satellite capacity currently allocated to AUTOSEVOCOM.

Table 4-1. Current AUTOSEVOCOM Gateway Terminals

US Service	Number of Terminals	WB Channels	NB Channels	Terminal Type
USN	5	3	5	AN/WSC-5
USAF	11	0	1	AN/TSC-102
USAF	5	0	2	AN/FSC-82
USA	?	?	?	AN/TSC-85A & 93A

Table 4-2. Current AUTOSEVOCOM Satellite Capacity

Satellite System	No. of Channels	Current Capacity
FLTSAT	2-(25kHz)	200 KHz
DSCS II	1 (Ch 2)	50 MHz/sat
DSCS III	1 (Ch 2)	60-75 MHz/sat

4.2 Mid-Term Candidates

Mid-term candidates rely on modifications to existing equipment that form a compatible operating mode with current systems. Some candidates tend to be more efficient in terms of SATCOM channel utilization while others expand the base of interoperable users. MT candidates also encompass equipments that are multi-function, single unit devices that are currently in a limited production stage. Such equipments may include vocoding, encryption and modulation in one unit or lightweight SATCOM modem/radio combinations.

4.2.1 Advanced Narrowband Digital Voice Terminal (ANDVT)

The ANDVT is one of the most promising UHF voice terminals because it solves interoperation problems such as voice encoding, variable rate digital data input, and encryption over a narrowband channel (roughly 4 kHz). This item is listed as a mid-term solution because it currently is in the development/production phase.

4.2.2 KL-43

Another promising secure data product is the KL-43 terminal that offers secure 300 baud TTY. Data encoding, encryption, and modulation are in one compact device.

4.2.3 Mid-Term Gateway Interoperation

There are a few methods within the Navy's secure voice subsystem network where gateways could be added to achieve dissimilar terminal operation. The central point is expanding functions of the AUTOSEVOCOM controller interface and providing the required translators. Such translators may perform multiple modem functions; first demodulate the Navy specific modulation type (i.e., SBPSK), then remodulate it into a different modulation form (i.e., USAF - OQPSK). Such translators could be realized by inserting the proper modem combinations in the baseband signal path. Similar translators could serve to change code rates, encryption devices, and digital voice algorithms; however, not all combinations are implementable with hardware.

The wideband channel accepts and transmits encrypted VF. The limiting factor in received digital voice is strongly influenced by the incoming digital data rate. A 2400-bps digital line qualifies as "acceptable" quality; however, this signal is typically of poor quality. If such a signal is re-converted to VF and then redigitized for transmission, the

captured VF borders on being inaudible.[3] If 16.5 kbps digital voice is used (i.e., CVSD) then capturing VF and redigitizing the signal with a 2400-bps algorithm is feasible.

Another function that the gateway must perform is translating frame formats since frame times and formats are grossly different among the services. A likely technique is to capture the baseband in one frame type and reenter these data on the other type of frame format. This would require that control information regarding frame size and slot delay/size would be necessary from both subnetworks. Buffering data into either network would also be necessary. These modifications to gateway terminals are extensive; however, they should be viewed as a trade off against the small population of gateway terminals when compared to the UHF terminal community.

4.3 Far-term Candidates

Far-term candidates are basic re-designs of terminals to support interoperability and candidates that show potential from the mid-term time frame. A major goal of far-term candidates is to achieve efficient channel utilization via DAMA networks. The Navy and Air Force are in the design and development stage of far-term candidates with the MACS and USTS specifications respectively. Another far-term candidate is development of gateways to increase interoperability of existing equipment that is not subject to interoperability constraints (i.e., validated user requirements).

4.3.1 Navy-MACS Modem

The Navy MACS modem was let to bidding (performance specification; Reference 27) but estimated construction costs were considered too costly. While the MACS modem program is currently suspended, the current plans were to re-specify its functions so re-compete bids for less functionality and lower cost may be obtained. The original performance specification describes the following interoperation capabilities:

- Non-DAMA operation
    - 5 kHz channel
    - 2.4 kbps

[3] Discussions with AUTOSEVOCOM transmissions Group - DCEC

- o secure voice

- TDMA/DAMA operation

  - o modulation: 1.2K BPSK, 2.4K OQPSK, 4.8K OQPSK

  - o TDMA 4 - data in a 8.32 sec frame format (6x1.3866...), choice of data, burst and code rates

  - o TDMA 5 - voice in a 1.3666... frame format

- Forward and return orderwires at 1.2 ksps, rate 1/2, and KGV-11 COMSEC

4.3.2 Air Force-USTS

The Air Force USTS are currently in the proposal/bidding cycle for contract awards. Four basic access protocols have emerged; a menu based TDM1 at 5 kHz, a fixed assignment frame, a packet DAMA, and the flexible frame. The Air Force performance specification (Reference 26) describes a traffic model itemized below. This model will be used to judge the technical performance of the various proposal efforts.

- Interoperability with TDMA 1

- Message lengths of 200 characters with exponential distribution

- 75% of I/O rate at 75 bps; 25% of I/O rate at 300 bps 8 bit characters

- Burst rates/distribution of 1.2/25%, 2.4/50% and 4.8/25% kbps

- Five levels of priority with highest to lowest distributed as: 3.2%, 6.5%, 12.9%, 25.8%, 51.6%

- Message interarrival time distribution: Poisson

- Multiple access voice at 4.8 kbps

- A dedicated 500 kHz channel at 2.4 kbps

The system specification describes a 5 kHz and a 25 kHz interoperability requirement in terms of two tables. These tables list various radios, modems, voice or data circuits and COMSEC devices that the USTS will interoperate with. When more than one mode of operation is listed (i.e., voice or data) then either mode satisfies the requirement.

4.3.3 Far-term Gateway Candidates

Far-term gateway candidates would support translation for all levels of the generic terminal. While a strong reasoning exists for gateway networks such as AUTOSEVOCOM, AUTOVON, and AUTODIN other networks such as the Defense Digital Network (DDN) may be examined along with grossly dissimilar equipment, such as Tactical GMF. Realistic far-term candidates would concentrate on translators between Army, Navy, and Air Force baseband differences. The Navy NAVCAMPARS and the Air Force AN/FSC-82 command post terminals are quite similar (AN/WSC-5 and AN/WSC-3 radios respectively). The Army's large tactical radio systems; however, are SHF, 48 Kbps PCM voice; hence, they are completely incompatible with the other services. Gateways may provide limited TTY type interoperability. Army gateway terminals would need to convert their 48 kbps PCM voice into analog, then re-convert the VF signal into the desired vocoding (ie. LPC-10 or CV3333). This would support interoperability without modifying the entire suite of GMF tactical terminals.

4.4 Generic Terminal Candidates

This section describes various elements of the generic terminal that offer distinct advantages toward solving interoperability problems. Criteria is based on the number of units currently in inter-DoD organization use, and/or their level of interoperability. Equipment with several modes of operation; for instance, qualify for a high level of interoperability. In some instances, the equipment is specified as TRI-TAC Joint equipment.

4.4.1 Source Processing Equipment

Data equipment character set differences between Navy and Air Force terminals can be resolved by using the following source processing equipment. The AN/UXC-4()(V) Baudot/ASCII fascmile terminal capable of six data rates between 1.2 to 32 kbps. It can be encrypted with KG-13 and KG-30 series encryptors. The AN-UGC-74()(V) Baudot/ASCII intelligent terminal that can compose, edit, transmit and receive operates with AC or DC power and is an AUTODIN mode IV terminal.

Secure digital voice could be solved for 25 kHz channels via the Digital Secure Voice Terminal (DVST) which uses a 16 kbps CVSD. This equipment also has a data port to secure data of the AN/UXC-4()(V) and AN/UGG-74()(V) terminals.

4.4.2 Encryption Equipment

Two types of COMSEC devices are well suited for interoperation because they are in widespread use throughout the DoD and they provide reliable security. The KG-30 series (KG-30 through KG-39) have roughly 10,000 units fielded which can all interoperate. An additional feature is their use as the COMSEC for all AUTOSEVOCOM systems.

The KG-84 is by far the most widely used data terminal COMSEC device as some 100,000 units are fielded.

The KY-57/58 (VINSON) digital voice encryptors are widespread (roughly 10,000 fielded units) throughout the DoD community but voice digitizing methods vary. These units would be recommended for interoperation if a standard can be established for the voice digitizing methods.

4.4.3 Coding Methods

Rate 1/2, 3/4, and uncoded convolutional coding ensure consistent coding. Codewords should be transparent and constraint lengths fixed. If rate 3/4 is available, it should not be based on punctured rate 1/2 coding.

4.4.4 Airborne Antennas

Omni-directional antennas typically lack sufficent gain (0 dBi) to establish an uncoded link using the 5 kHz channels. An alternate antenna candidate may rely on multiple high gain antennas (i.e., 6 dBi) that can be switched by the user depending on which provides the highest link margin.

4.5 Follow-on Satellite Recommendation

Secure voice links to disadvantaged satellite terminals using the 5 kHz SATCOM channels such as aricraft are marginal without coding. An obvious recommendation is to increase the power level on some of the 5 kHz satellite transponders to permit secure voice communication with these platforms. This would permit use of the interoperable uncoded waveform that could provide secure voice between manpacks and aircraft. Since most of the 5 kHz channels are to support manpack operation it is unnecessary to provide increased power (beyond 20 dBw EIRP) to all the 5 kHz channels because their antennas provide 6-7 dBi of gain.

5 Summary and Conclusions

This report has presented definitions for interoperability, previous and current policy, types and estimates of current equipment quantities and candidates for interoperability standards. Recommendations on interoperability must be evaluated against cost and time for implementation into a practical system. Near-term recommendations suggest DoD organizations interoperate with terminals that have common modes of operation, or common network access like the AUTOSEVOCOM and AUTODIN networks. Mid-term recommendations are standardized baseband equipment like the ANDVT. Far-term recommendations include an evaluation of the near and mid-term recommendations with common techniques applied to various elements of the generic terminal.

The identification of interoperability requirements and the levels of interoperability is fundamental. A number of operational crises have occurred where interoperable communications or the lack of interoperable communications has been identified as a significant factor in the outcome of the operation. This has placed emphasis on interoperability, but has not yet led to the defining of interoperablility requirements. The current approach emphasizes the development of standards for UHF terminals and the definition of interoperable modes for new equipment. This together with testing should result in interoperable equipment for the far-term. Backward compatibility of new equipment with older equipment is necessary during transition to new standards to preserve communication capability. Transition to new standards and interoperable modes are often slow, but are often less costly than modifying fielded equipment.

6 References

1. Dr. Jon Boyes, Vice Admiral, USN (Ret.) "Tactical C^3I Interoperability and The Somme," Signal, (November 1985).

2. "UHF MILSATCOM Follow-on System," Memorandum for Deputy Under Secretary of Defense for Research and Engineering (C^3I), Director for Command, Control and Communications Systems (C^3I), Organization of the Joint Chief of Staff, Defense Communications Agency, Washington D.C., (July 1985).

3. "UHF Manpack Portable SATCOM Terminals," Memorandum for the Assistant Secretary of Defense for Command, Control and Communications Intelligence (C^3I) Defense Communications Agency, A800, Washington D.C., (November 1985).

4. M/A-COM LINKABIT, Inc., Draft DoD TDMA/DAMA Waveform Standard for 25-kHz Satellite Channels, under contract DCA100-84-C-0009 for MILSATCOM Systems Office Code J800 (October 1984).

5. M/A-COM LINKABIT, Inc., Draft Specification for DoD Standard 5-kHz DAMA Structure, San Diego, Ca. (July 1984).

6. Naval Ocean Systems Center, Navy UHF Satellite Communications System Description, San Diego, Ca., for Naval Electronics Systems Command PME-106, Washington, D.C. (January 1978).

7. Performance Specification for the ANDVT Tactical Terminal, Contract N00039-79-C-0002, Joint Tactical Communications Office, Ft. Monmouth, N.J. (January 1983).

8. Frank M. Brauer, Secure UHF Satellite Communications for the 1990's, Cincinnati Electronics Corp. for Aerospace America (June 1985).

9. P. D. Engels, Air Force UHF Satellite Communications Demand Assignment Multiple Access (DAMA) Systems Requirements, MITRE Corp, Bedford, Ma., under ESD Contract F19628-84-C-0001, Mitre Technical Report, MTR 9893 (November 1985).

10. Rockwell International, Air Force Satellite Communications System, Training Manual Systems Overview, Collins Radio Group, 523-0765641-003118, (November 1975).

11. H. Paul, Systems Level Analysis for Demand-Assigned UHF Time-Division-Multiple-Access Satellite System, Vol I & II, Appendix G, Computer Sciences Corp., Falls Church, Va., CSC/TR-75/3012 under contract N00039-73-C-0036 for U.S. Navy (PME 106) (December 1974).

12. USAF Follow-on UHF MILSATCOM Requirements and Architecture, via Capt. David F. Kassander, USAF HQ AFCC/XPQCC, Space and C^3 Systems Office, Scott Air Force Base, URDB (February 1986).

13. Jack Garner, Tim McChesney and Michael Glancy, "Advanced Narrowband Digital Voice Terminal," Signal (November 1985).

14. Mitre Corp., Air Force Satellite Communications (AFSATCOM) System Document, Bedford, Mass. under ESD contract F19628-81-C0001, Mitre Technical Report MTR-3935 (July 1981).

15. Qualcomm, Title Unknown, Subject Technical Analysis and Cost Estimate (TA/CE) for Developing UHF Satellite DAMA Equipment to Satisfy USCINCLANT ROC5-84, San Diego, Ca., Sponsored by JTC^3A (C3A-ARJA), JTC^3A Report 8201 (April 1986).

16. M/A-COM, Flexible Frame Demonstration, M/A-COM Proprietary, IR&D, San Diego, Ca., Demonstration Handout Viewgraphs (April 1986).

17. Memo: UHF SATCOM Implementation Status, Commander, Naval Electronic Systems Command, 11019/PME106-11/WCW (Circa 1982).

18. Mitre Corp., UHF SATCOM Terminal Characteristics, under contract F19628-86-C-0001, Task Order Number AE07, Mitre TL3680-01 (January 1986).

19. M/A-COM Government Systems Division, Channelization Considerations for PSK Modulation Techniques in Follow-on UHF MILSATCOM Systems, under contract DCA 100-84-C-0009 for MILSATCOM Systems Office (April 1986).

20. Tracor Applied Sciences, Inc. (ESD), AN/WSC-3(V) and AN/PSC-3(V) Compatibility with CV-3591(XN-1) Advanced Narrowband Digital Voice Terminal, Satellite Communications Dept. contract N00421-84-C-0016, TDL # 84/T-0253-80-006 (November 1984).

21. W. Blohm and LTC W. Brown, USAF "Joint Tactical C^3 Architecture," Signal (November 1985).

22. Discussions on: Draft - ANDVT/UHF SATCOM Radio Interface Evaluation/Operation Test Report, Naval Electronic Systems Engineering Activity, St. Inigoes, Md. (May 1986)

23. Richard Jolly, AFCC Staff Study UHF SATCOM Radio Terminals (Manpack, Transportable and Fixed), 1842nd Airborne, Scott AFB, Ill, 62225-6348, 1842 EEG/EETTS (March 1986).

24. Computer Sciences Corp., Upgrade Design Plan Recommendations for FLEET SATELLITE BROADCAST (U), prepared for PME 106-1, under contract N00039-80-C-0180, (SECRET) Computer Sciences Corp. (June 1980).

25. UHF SATCOM Terminal Technical Criteria, Memorandum for Assistant Secretary of Defense (Command, Control, Communications and Intelligence), Director for Command, Control, and Communications Systems, Organization of the Joint Chiefs of Staff, Wash., D.C., Defense Communications Agency, A800 (August 1986).

26. Hanscom Air Force Base, Ma., System Specification USTS-S-101 UHF Satellite Terminal Systems (USTS), Electronic Systems Division (ESD/OCMM) (June 1986).

27. Multiple Access Satellite (MACS) Modem, Airborne Full Scale Development Specification, Naval Electronic Systems Command Contract Specification, (Draft), ELEX-M-631 (March 1985).

28. System, UHF SATCOM Automatic DAMA Control, Naval Electronic Systems Command Specification, ELEX-S-622 (March 1985).

29. The Defense Satellite Communications System - Ground Mobile Forces (DSCS-GMF) Interface Operations Support Concept, DCA Circular 800-55-4 (Draft), Defense Communications Agency (August 1985).

I Spectral Inversion

Spectral inversion (Reference 11) is a an IF/RF mixing phenomena of phase modulated systems that is characterized by the reversal in sign of the signal. It is the result of the multiplicative process in upconverting that causes the lower sideband (the carrier frequency $\{\omega_c\}$ minus the IF $\{\omega_{IF}\}$) to undergo spectral inversion. The transmit signal may be composed of either or both upper and lower sidebands, hence it is a function of $(\omega_c \pm \omega_{IF})$. The downconverted received signal may produce four possible outcomes that are a function of the IF, a channel phase delay, and the normal or sign reversed phase data. Two of the four outcomes are sign reversed. Spectral inversion manifests itself in different ways as a function of forward error correcting algorithms and modulation techniques. Three important assumptions for this analysis are that differential encoding, transparent codewords (where applicable) are used, and FEC is done after encoding and before decoding (i.e., FEC is the inner code and differential encoding/decoding is the outer code). Differential encoding ensures that regardless of data sense (0 or 1) the transition criterion for differential encoding will correct inverted data. Transparent codewords have the property that the complemented codeword will complement the data output. The recommended technique is using FEC as an inner, transparent coding technique with differentially encoding/decoding as the outer code. Reversing their order could cause errors beyond the FEC correcting capability. This happens because differential decoding before the FEC would double the input error rate to the FEC. Differential decoding after the FEC output removes the sign ambiguity, thus increasing the output bit error by some factor less than 2. Corrective action to spectral inversion is based on the error in phase of the reference to the recovered carrier in the receiver. Depending on modulation this error can be zero to $\pm\pi$ radians. For the purposes of interoperation, two types of post process demodulation algorithms would have to be implemented in order to realize compatibility. The types of correction require bit complement, bit reversal, or their combination to realize the data. In some cases the correction action may double the received random bit errors; however, at small bit error rates this should not pose a problem. Table I-1 lists the corrective action and effect of bit error as a function of modulation. This table assumes that either the transmitter or receiver is spectrally inverted and the other transceiver is not.

Table I-1. Corrective Action for Spectral Inversion

Modulation Type	Phase	Corrective Action	Random Bit Errors
BPSK	$\pm\pi$	complement	doubled
BPSK	zero	same	same
BPSK-FEC	π	complement	doubled
BPSK-FEC	zero	same	same
QPSK	π,0	same	same
QPSK-FEC	$\pm\pi/2$	reverse&complement	same
OQPSK	$\pm\pi/2$	same	same
OQPSK-FEC	$0-\pm\pi/2$	reverse&complement	same

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A173 202 #1465

73

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188 Exp. Date: Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY: N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT: Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): Report No. 183, Log No. MSO-86-082a	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: M/A-COM Government Systems, Inc. — 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: Defense Communications Agency, MILSATCOM Systems Office, Code A800
6c. ADDRESS (City, State, and ZIP Code): 8619 Westwood Center Drive, Vienna, VA 22180	7b. ADDRESS (City, State, and ZIP Code): Washington, D.C. 20305-2000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Defense Communications Agency — 8b. OFFICE SYMBOL (If applicable): A800	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code): 8th & S. Courthouse Road, Arlington, VA 22204	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
UHF Military Satellite Communications Ground Equipment Interoperability (U)

12. PERSONAL AUTHOR(S)
Michael Furman

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 7/15/86 TO 10/6/86	1986 October 6	73

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	UHF MILSATCOM, Interoperability

UHF

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

(U) This report addresses interoperability among users of ~~Ultra High Frequency~~ UHF Military Satellite Communications (UHF MILSATCOM). Prior to identifying well-defined requirements for interoperability, each service developed equipment meeting its own requirements, but with little capacity for interoperating with other services' equipment. This report presents UHF interoperability from two major viewpoints: technical and managerial. It gives the reader an idea of what has been done and recommends solutions to enhance interoperability between the services and special user groups in a tactical environment. It summarizes and comments on directives and studies addressing UHF MILSATCOM interoperability. It considers interoperability from user to user, including source processing, waveform processing, radio frequency, intermediate frequency, and network considerations. It addresses seven levels of interoperability.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL: William Long	22b. TELEPHONE (Include Area Code): (703) 692-0280 — 22c. OFFICE SYMBOL: A810

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

END

12-86

DTIC